MINING ENGINEERING

JANUARY 1949

Blasthole Stoping

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Mining Geophysics

•

Wesco—Lowest Cost Industrial Mineral

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Heavy-Media Separation

A MONTHLY PUBLICATION OF THE
AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS
MINING BRANCH

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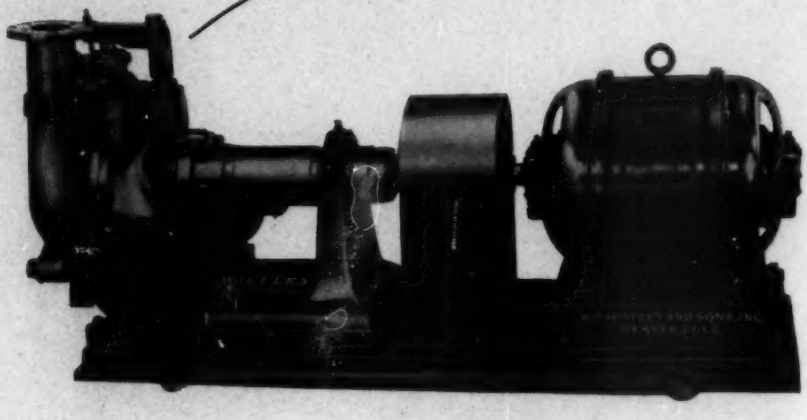

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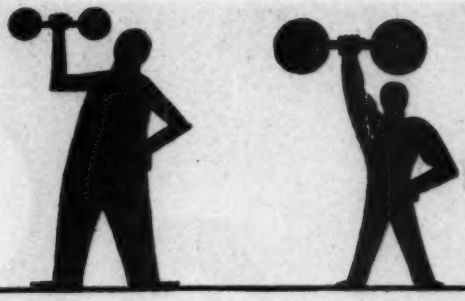

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in which is incorporated Mining and Metallurgy, Mining Technology and Coal Technology

JANUARY 1949 VOLUME I, NO. 1

Cover photograph illustrates diamond-drilling blastholes. Courtesy of National Film Board, Canada.

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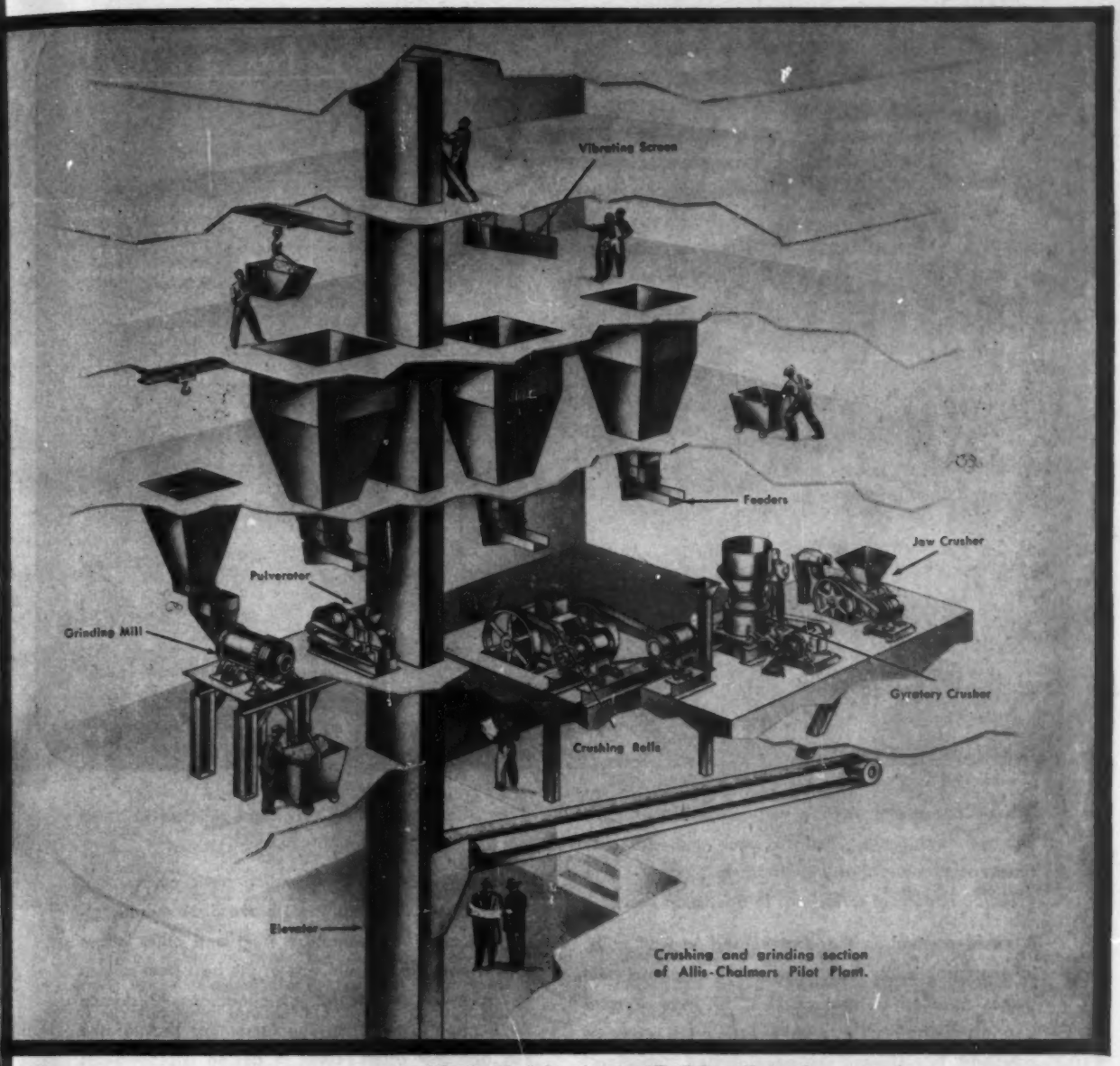

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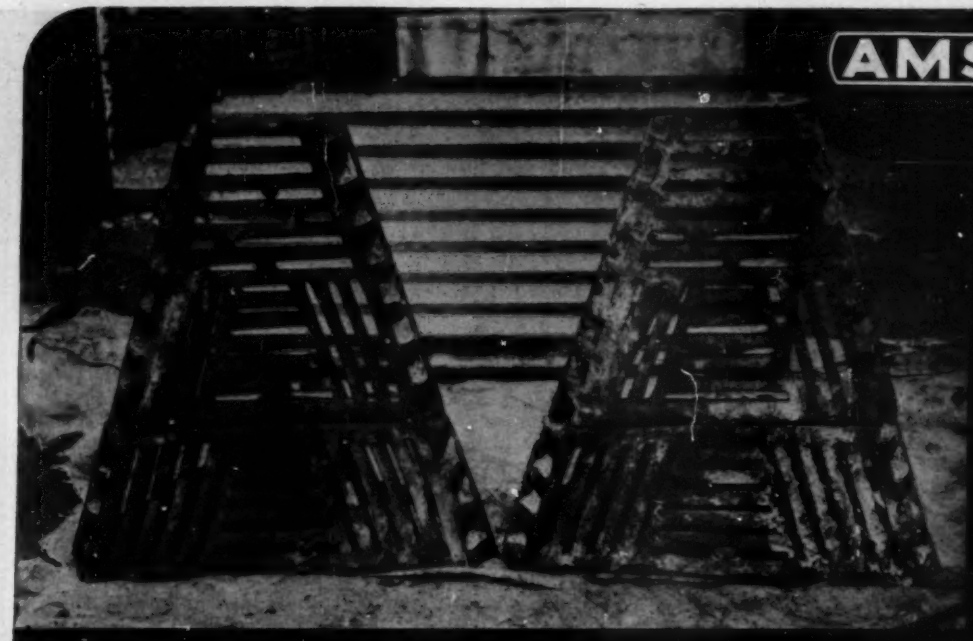

Unretouched illustration of Amsco special manganese steel grates . . . after handling 193,797 tons of gold bearing quartz rock in ball mill.

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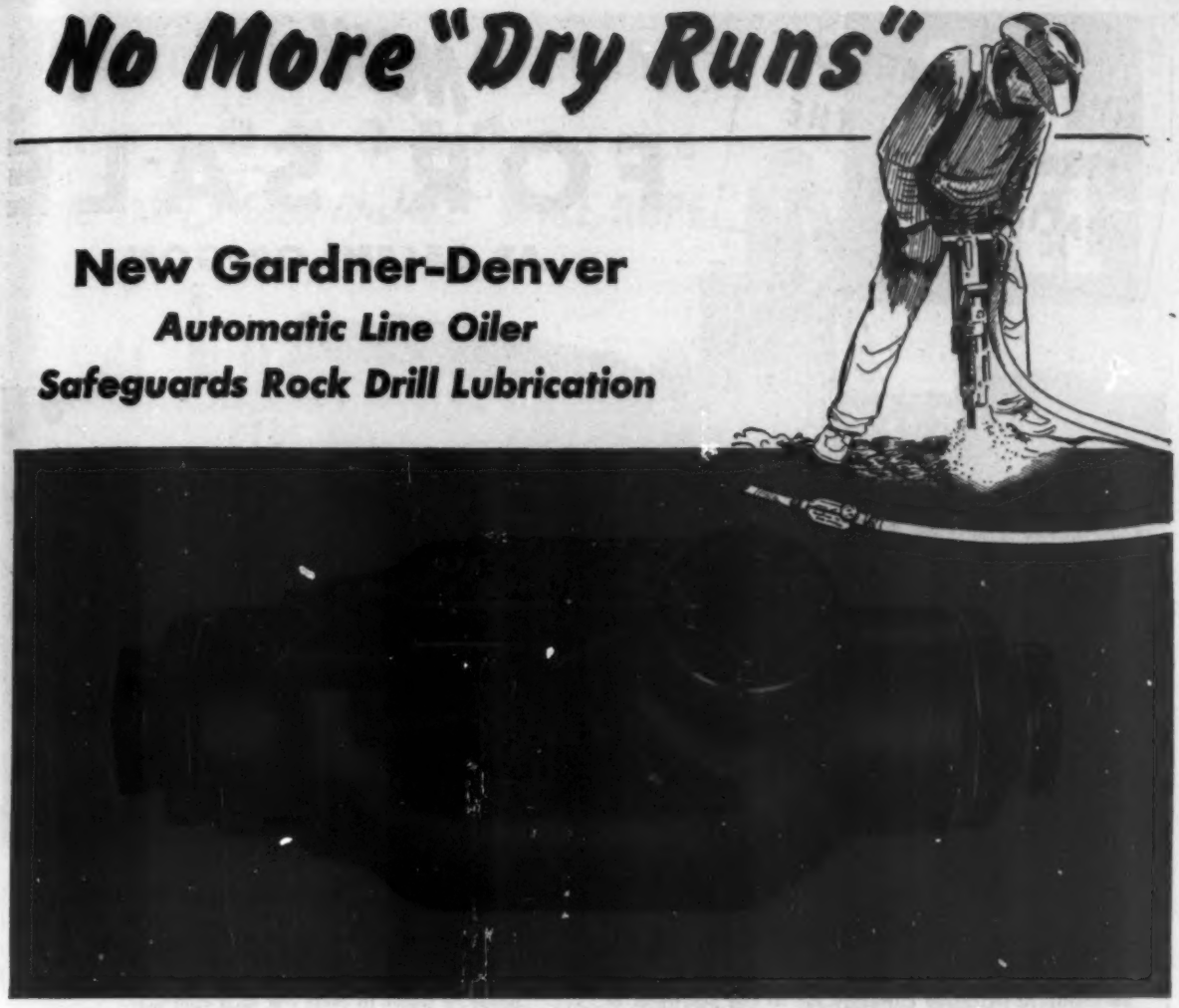

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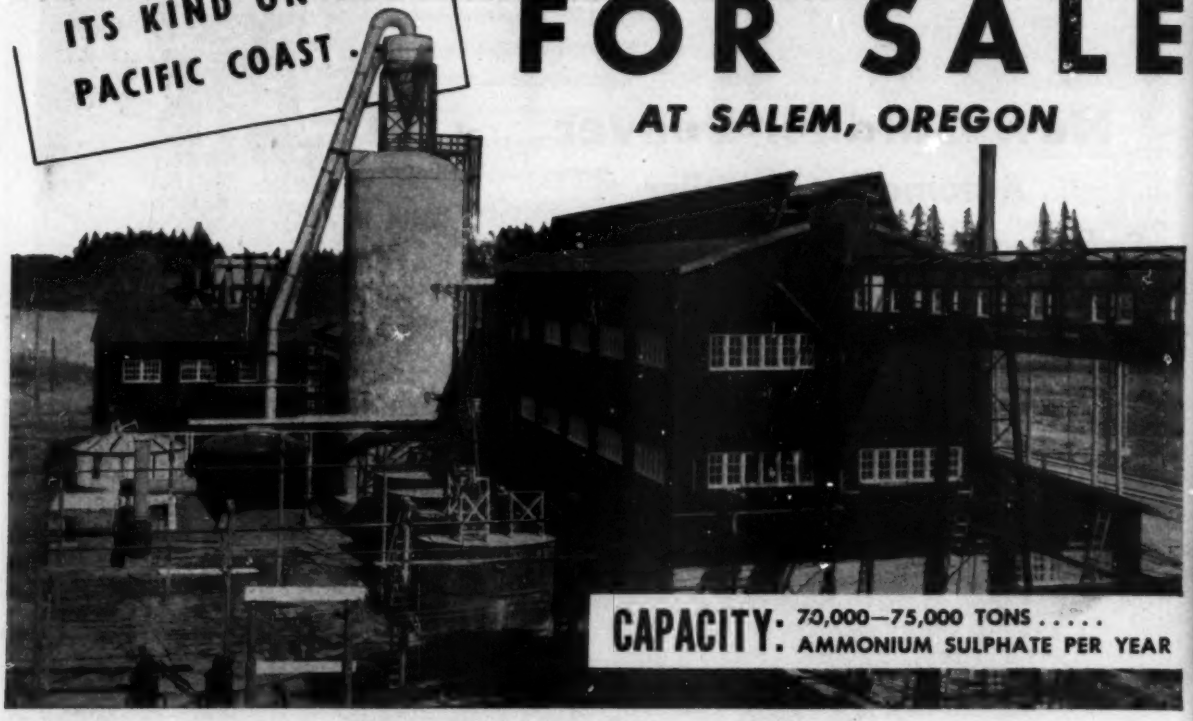

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(2) That portion of the facility usable for the present capacity production of ammonium sulphate is subject to provisions of the National Security Clause. This means that the Federal Government retains dormant rights to use these facilities under Government contract. In the event that this dormant right is exercised, the Government will consider the qualifications of the buyer or lessee to carry out such contracts.

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a. Dismantle, salvage or sell all remaining personal and real property; or

b. Dismantle, salvage or sell the remaining personal property, and use the cleared real property for general manufacturing purposes.

(4) The present lessee has been informed of this offering.

SEALED BIDS for the purchase of this plant will be received until 2:00 PM, E.S.T., February 2, 1949, at the address given below. All interested parties are urged to write at once for an illustrated brochure, necessary bidding instructions and an appointment to inspect the property.

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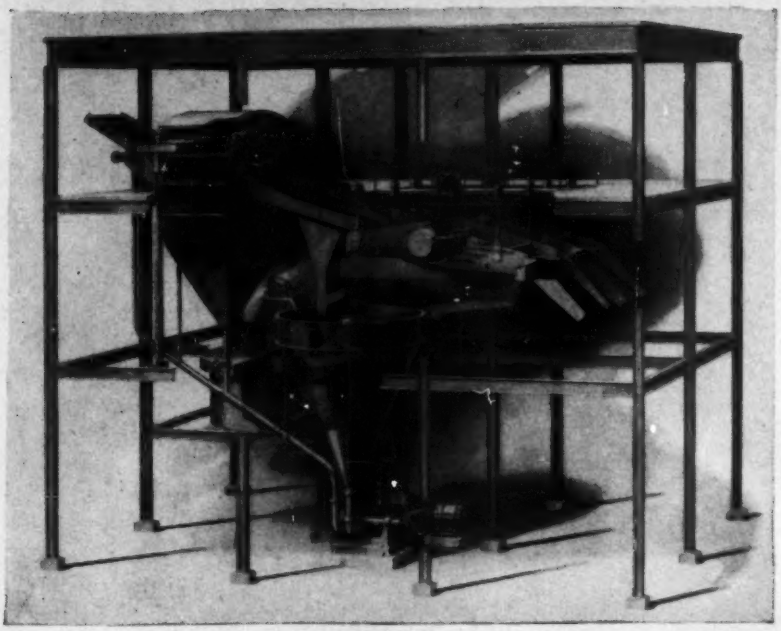

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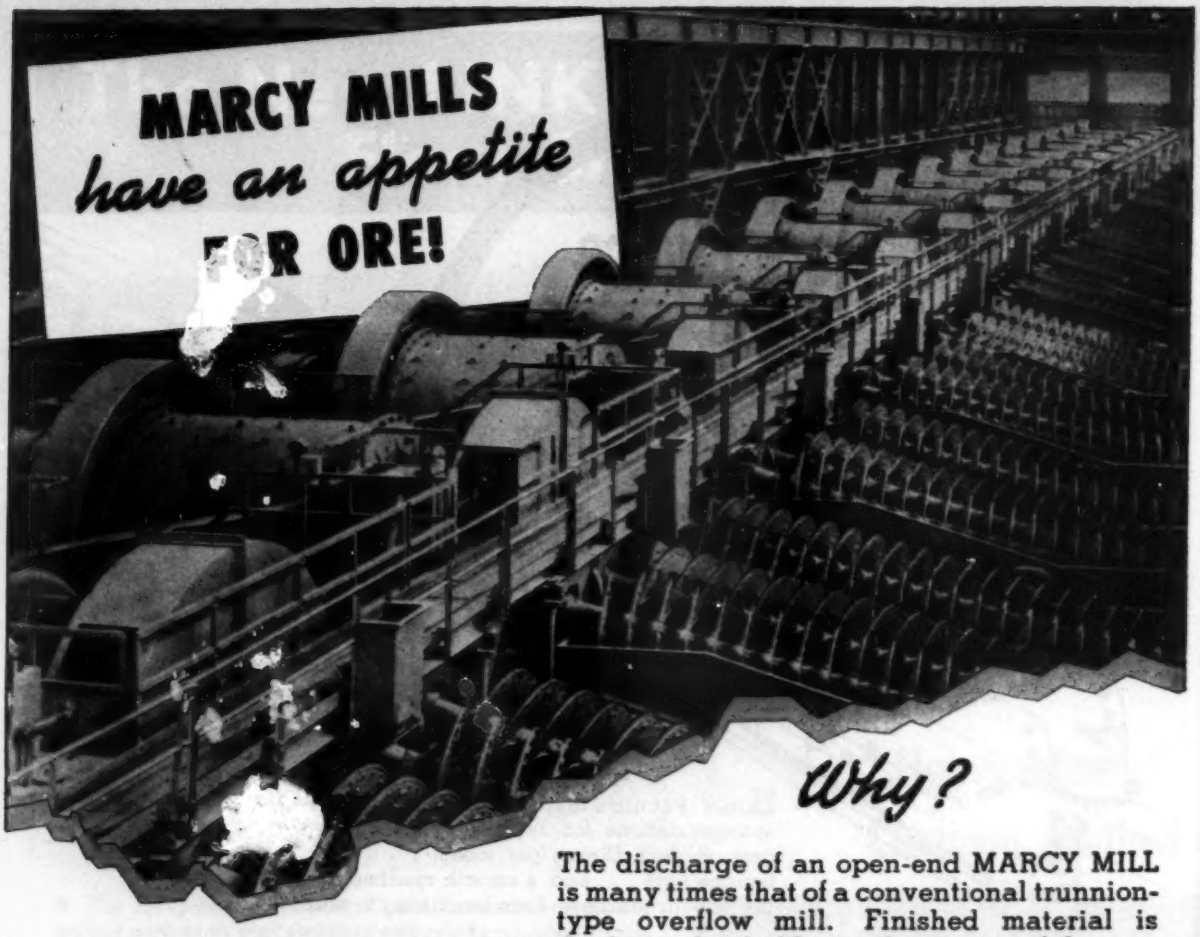

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XUM

MINING ENGINEERING

Our First Issue

MINING ENGINEERING herewith makes its bow to all those members of the AIME and former subscribers to *Mining and Metallurgy* who are primarily interested in mining geology and exploration, and in the mining and beneficiation of metallic and nonmetallic ores and minerals, and in the mining, preparation, and utilization of coal. Separate editorial staffs will be responsible for the *Journal of Metals*, which will also be published in New York, and for the *Journal of Petroleum Technology*, which will be published in Dallas, although there will be the closest cooperation between all three.

One section—section 2—will be common to all three journals and will contain, for the present, the type of material you will find in this issue. If members of the Mining Branch are not interested in any particular features of this section, the editor would like to hear from them, for only matter of supposedly broad interest to readers of all three journals is intended for this section.

We prefer to make a modest start with MINING ENGINEERING and improve with each issue. We have many plans for expansion, but unfortunately they all cost money and will be adopted as fast as income from the sale of advertising and subscriptions warrants, or money is made available from other sources. Members of the Institute can assist in several ways. One is to call the attention of suppliers to the new magazine and urge them to use it as an aid in their selling; another is to give preferred treatment to our advertisers; another is to enter a subscription for company reception rooms. Members can aid also by contributing articles or shorter material to our pages; by telling us where interesting things are happening so that we may approach possible authors; or by sending us interesting photographs. Critical comment on the new publication policy will also be welcomed.

California, Here We Come

Though attendance at the Annual Meeting in San Francisco is unlikely to be as large as that for a meeting in New York, owing to the much smaller group in the immediately adjacent territory, the technical program is the most imposing of any Annual Meeting in Institute history. The preliminary program, as published in this issue, indicates that 66 technical sessions will be necessary, practically all of which must be crowded into four days. That means an average of about eight sessions going on at once throughout the meeting, so it will be quite important for one to plan where he most wants to be. In general, the papers will appear on a program in the order listed so that one may hear an early paper on one program and then move

to another room for a later paper on another program, although the presence or absence of authors at a certain time may result in revising the time of presentation. Probably some members will find that sessions in which they are particularly interested are running concurrently, but every effort has been made in planning the sessions to avoid the most likely conflicts. Night sessions will be avoided, as has been the custom in the past, for six hours of technical fare a day is quite enough, and plenty of opportunity for recreation will be available at night.

Undoubtedly, a larger attendance of practical operating mining men will be registered than ever before, and discussion of geological, mining, and milling papers should be as interesting as the papers themselves. Much of this discussion never gets into print, so only those who are there will get the benefit.

And by no means overlook the little article in this issue by Herb Rose on how to attend an annual meeting, and why you should be there.

Last Aluminum War Plant Sold

After three years of negotiation, the War Assets Administration has finally divested itself of the last of its important aluminum producing properties. The Government's plant at Massena, N. Y., next door to the long established plant there of the Aluminum Company of America, has been sold to that Company for five million dollars. Included in the contract is an agreement to make available to others, on a reasonable license basis, all of the Aluminum company's alloy patents and its most important process and fabricating patents, without reciprocal obligations by others.

The Aluminum company will move some of its operations from its older plant to the new, and will spend, in addition to the purchase price, some $2,750,000 to put it in operation. The older plant will be kept in a stand-by condition for emergencies. Included in the contract is also provision for the sale to the Aluminum company, for $175,000, of certain carbon-producing equipment from the Government's Burlington, N. J., plant, which will be transferred to the new aluminum smelting plant at Port Comfort, Texas, permitting it to go into operation several months sooner than otherwise, and thus helping to relieve the current shortage in aluminum.

Three companies, instead of one as before the war, are now responsible for the country's aluminum output: the Aluminum Co. of America, the Reynolds Metals Co., and the Permanente Metals Corp., the last named, one of Henry Kaiser's companies. Their ratio of aluminum-producing facilities is about 50-30-20. Aluminum production by both Reynolds and Permanente is royalty free, though the Aluminum company held patents on many of the processes and equipment that the other two companies use.

Not much is now left of the old aluminum monopoly, but its long experience and know-how and entrenched position in the market should still give it an advantage over its competitors. How well this advantage is to be maintained will be largely up to the astuteness of its management. Even though it can have but half of the United States market, that market is now seven times the prewar average (1936-39) when annual consumption was 160,000 tons. No other common metal has witnessed anything like such an increase in demand. Consumption of aluminum has almost attained that of copper. Measured on a cubic foot or square foot basis, which is the way the aluminum people like to talk about their light metal, the consumption of aluminum is much greater than that of any other nonferrous metal.

Geological Societies Form Over-all Institute

Announcement was made in November of the final completion of the new organization to embrace all the geological societies of the country, to be known as the American Geological Institute. Probably few mining men realize it, but there are eleven national societies in the country more or less interested in geology, with a combined membership of some 10,000 geologists, and it was these that united in forming the over-all institute. Among its objectives are speeding up the discovery of additional reserves of scarce minerals, furthering the detailed geologic mapping of the United States, greater use of geologists by Government agencies and the armed services, the training of more geologists, improvement of education standards, more effective dissemination of research information, and greater public understanding and appreciation of the role of geology in modern civilization. Matters of this kind can be supported better by such an organization than by an individual society whose interests are usually in more specialized and strictly professional fields. Likewise in engineering, there are some matters on which some joint organization of engineering societies can speak with more authority for the whole engineering profession than can any one professional group. Some years ago the American Engineering Council was set up to carry out such an idea but it finally expired. In recent years its place has been taken by a less pretentious group, the Engineers Joint Council, made up of the presidents, immediate past presidents, and secretaries of the four Founder Societies plus the American Institute of Chemical Engineers.

We welcome the new geological institute, of which the AIME is one of the constituent societies, and wish it well. Its president and vice-president respectively are AIME members of thirty years' standing: A. Irving Levorsen, who was chairman of its organization committee and is dean of Stanford's School of Mineral Sciences, and William B. Heroy, consulting geologist and vice-president of the Geotechnical Corp., of Dallas. Earl Ingerson, of the USGS in Washington, is secretary-treasurer. Headquarters will be at the National Academy of Sciences, 2101 Constitution Ave., Washington, with which the new institute is closely associated.

Besides the AIME, the societies thus joining forces are:

Geological Society of America
American Association of Petroleum Geologists
American Geophysical Union
Mineralogical Society of America
Society of Economic Geologists
Society of Exploration Geophysicists
Society of Economic Paleontologists and Mineralogists
Seismological Society of America
Paleontological Society
Society of Vertebrate Paleontology.

XUM

Blasthole Stoping Evaluated

diamond drilling for breaking ore is here analyzed on the basis of an extensive survey by questionnaire—future outlook appraised

By VINTON H. CLARKE • MINING ENGINEER, HOWE SOUND CO.; AND
JOHN V. BEALL • MANAGING EDITOR, MINING ENGINEERING; MEMBERS, AIME

Diamond-drill blasthole stoping has now been used for a long enough time to permit us to discuss fairly its problems from the ore-breaking angle and to attempt to peer into its future. To do this we have gathered information from many properties through questionnaires. The operators have indicated fairly well in their answers what they think of the method. The many variations of methods have by now been fairly well developed, and performance rates and mining costs are well established at each property. All this can be laid down on paper with fair completeness. Now, knowing all this, what will the future of the method be?

To attempt to look into the future of a mining method immediately brings to light many problems and variables. For instance: why were diamond drills used in the first place? What has the cost trend been? In what type of deposit has the method proved most advantageous? What will the future cost of diamonds be? What are the possible substitutes?

Diamond drills were used in the first place principally for three reasons: (1) to drill longer holes than could be drilled with conventional percussion drills and extension steel, thus decreasing the development work necessary; (2) to drill ore that was so hard it was best drilled with diamond bits; and (3) because of safety advantages. In mines where one or more of the above advantages applied and the over-all cost of the new method was found less than the old, diamond-drill ore breaking expanded and variations of methods were devised. When man-power shortages began to be felt, some operators seized on the diamond-drill blasthole method to produce more tons per man-shift. At this time the cost of the method was of less importance than the fact that the mill could be kept running.

As long as the cost trend is on the decline we are satisfied. Costs will show improvement with the diamond-drill blasthole method of mining as long as techniques and man-power efficiencies improve. When the method everywhere is as highly developed as it is in many mines using it now, this declining curve will straighten out and eventually rise, in line with supply and labor increases. Then is the time to look for new methods or radical new techniques.

Diamond-drill blastholes show to their best advantage under the following conditions:

(1) Pillars, which are usually hard to take out safely.
(2) Ore that stands well, i.e., at least well enough to permit the use of shrink stoping, or cut and fill with the cut being thirty or more feet long.
(3) Ore that has a definite wall or walls to which blast will break.
(4) Nearly any ore body that will permit open stoping where the stope is over 30 ft wide. This width varies, of course, depending on the ore breakability. One case has been reported where a vein width of only 5½ ft has been successfully broken with but one hole in the center of the ore.
(5) Ore body with fairly regular walls, i.e., regular enough so that holes can be drilled at least 30 ft long along the hanging wall if flat holes are used. With the vertical ring system, following rings must not have too acute an angle to break to, again depending on the ore breakability.

As to the future cost of diamonds, and possible substitutes therefor, unfortunately we cannot look for any cut in the price of diamonds in the immediate future. Actually we can expect a still higher price. Substitutes are coming into the field to a limited extent but have not made their weight felt to any great extent.

Drilling for breaking ore by this method is done in a variety of ways, but all fall roughly into two categories, either vertical or horizontal rings. Under the vertical heading come the two main methods, the Noranda and the Aldermac methods, each developed at the property named.

In brief, the Noranda method (Fig. 1) is the drilling of vertical rings of holes from two drifts usually on the hanging and footwalls, the holes fanning from the drifts

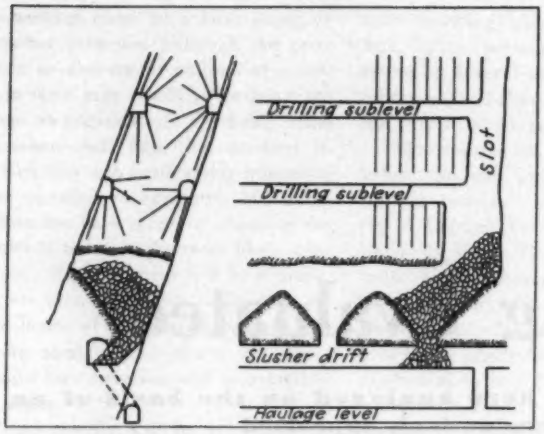

Fig. 1. Noranda method—drilling vertical rings from subdrifts.

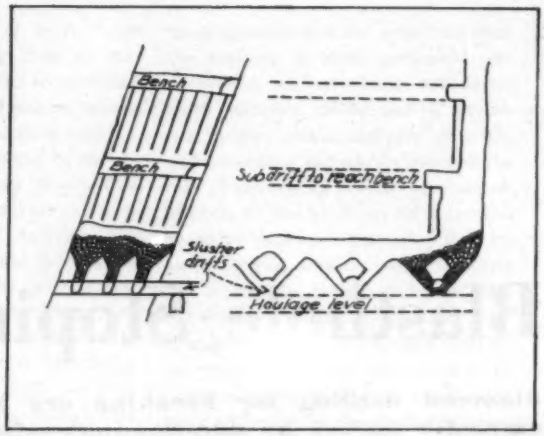

Fig. 2. Aldermac method—drilling parallel holes from bench.

toward each other to form a network of holes as equally distributed through the ore as possible. Each ring is successively blasted to a previously prepared slot. Rings may be drilled down from each set of drifts and ore broken in benches, or the rings may be fanned both down and up so that long vertical slices can be blasted.

The Aldermac method (Fig. 2) takes advantage of the perfect hole distribution made possible by drilling parallel holes. Usually only the footwall drift is driven to the slot. Then a slice of ore is sideswiped across the ore to the hanging wall from the footwall drift just wide enough to give clearance for the drills in drilling the desired holes. This procedure is repeated after each set of parallel holes is drilled and blasted.

Horizontal drilling usually takes the form of parallel or ring drilling. Parallel drilling can be done from a slot across the ore body from the foot to the hanging wall, drilling more or less parallel to the foot and hanging walls and breaking to the undercut. It can also be done from a slot on the footwall, the holes being drilled into the hanging wall. The plane of holes can be tipped to become normal to the walls or at any angle desired.

Horizontal ring drilling (Fig. 3) is done from raises on the foot and hanging wall or the footwall only. Holes are fanned from each raise to form a network similar to that in the Noranda vertical system. Where conditions are favorable for breaking, no raises are required on the hanging wall. With distinct foot and hanging walls, raises may be placed in the center of the ore body.

Many variations of the horizontal and vertical systems exist. A system of inclined rings composed of up holes has been used to recover ore overhead on a retreating basis. Parallel vertical holes have been used to enlarge a central raise on a regular stoping procedure. Parallel horizontal holes have been used as a direct substitute for percussion-drill overhand or breast stoping.

Of the mines reporting, most are sulphide replacement deposits with varying degrees of silicification. One is a limestone mine and two are gold mines with little sulphide content. All except one dip steeply and so lend themselves nicely to d-d blasthole methods of mining, though there is no reason, of course, why diamond drills cannot be used in flat tabular deposits if costs will permit. In extremely hard rock they have sometimes proved advantageous. In softer rock they usually do not show any benefit as it is nearly always necessary to place a burden on them which, in itself, will show a comparative economic result; but various other problems, such as poor fragmentation, muck pile thrown too far from working face, and too much back break (shattering of walls), counter-balance the advantage of increased burden.

An examination of the tabulation sheet indicates that most mines have a vein thickness of over 30 ft, indicating that with thinner veins, stopes are generally mined by some other method. The one mine using the Noranda and horizontal hole methods, on an 18-ft vein thickness, states that the methods are being changed due to high cost and excessive wall shattering and subsequent dilution. There are exceptions, of course, a case in point being the extremely narrow vein application mentioned earlier.

For the most part, walls are regular and must be so to be able to follow the foot and hanging walls with horizontal holes of a suitable length. With vertical holes, it becomes difficult, in average ground, to blast following rings around a corner with a deviation of more than 20 degrees from the straight line. It can be done, but extra holes must be drilled and chances of breaking troubles are greatly increased.

The size of block to be mined is largely dependent on the type of deposit. Strong, firm walls and ore lend themselves well to large open stopes and a resultant lower development cost for all blasthole methods. The above conditions may be present in some young mines on the upper levels and every advantage should be taken of them. However, it is well to remember that as the stoping reaches greater depths, rock pressures begin to deal a new hand and, even in the strongest rock, stopes must be made smaller in size; the stoping sequence must be an orderly retreating one where fill is used. Some mines are retreating along levels and allowing the open stope to cave as it will, but here they have found it wise to shorten the level interval. At various stages of mining, operators have found it necessary to leave pillars either because of low-grade areas or for support. In the mines having softer, weaker ore and walls, various forms of shrink and

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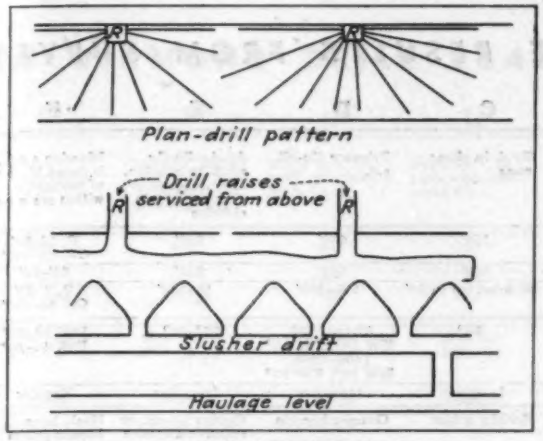

Fig. 3. Horizontal rings drilled from footwall raises.

cut-and-fill methods have been used in conjunction with diamond drills and here definite size stopes have been worked out. Examining the tabulation sheet we see that the width (length along strike) of the block to be mined varies from 80 ft to a maximum of 400 ft, indicating an average in the neighborhood of 150 to 200 ft. Level interval or height of block varies from 50 to 500 ft, but most mines are using a stope height of between 150 and 200 ft. It is well to stress again the importance of the statement that rock conditions at each property are different and are of varied importance in the determination of the size of block to be mined. No two mines are alike and those factors which have produced a successful mining system at one property cannot arbitrarily be applied to another. We can, however, by observing results at several mines, determine within limits the factors which will produce success or failure of the system at any other property.

In undertaking a system of mining using diamond-drill blastholes a certain amount of dilution should be expected, the amount determined of course by the type of wall rock present on both foot and hanging walls. Nearly all the mines reporting have shown that a certain amount of caving or sloughing is present and, naturally, nearly always from the hanging wall. Only when extremely weak rock is present, as is indicated in two or three instances, is there caving from the footwall. One reason for changing to the d-d blasthole system of mining at some properties has been because of a lower dilution factor as compared to other methods of heavier blasting, such as powder blasting with coyote holes, which tends to shatter the walls. At the same time, as mentioned before, this dilution has been the reason why some properties have had to abandon blasthole mining itself in favor of another lighter blasting method. It is strictly an economic problem depending on the amount of dilution one can afford in order to take advantage of the benefits of the system. It is also a problem that may take years of trial-and-error testing to solve.

In choosing a method of mining it is advantageous to have definite hanging and foot walls to which blastholes will break. The reports indicate that these conditions exist in slightly over half of the cases. If walls are particularly well defined much development work can be eliminated by taking advantage of this fact. In mine "L," a drift has been driven down the center of the ore body and holes have been "dead-ended" into the hanging and footwalls in radial rings. The same thing can be done with horizontal rings or rings on an inclined plane from raises. In mines having poorly defined hanging and footwalls or commercial walls, holes can sometimes be "dead-ended" by taking advantage of the hanging wall dip. The angle to which the end of the hole will break freely is dependent on the character of the ore to be broken and must be determined by testing. Factors which determine the ore breaking qualities must also be taken into consideration. For instance, is rock more or less homogeneous, to what degree are fracture planes present and in what direction, and what is the rock structure and its direction? A more or less homogeneous rock will tend to break where the holes are drilled and it will produce an evenly sized product. A vein crisscrossed with slips and fractures also will break closely to the line of holes and will produce a small, evenly sized product. A vein having fewer slips and fractures may begin to cause trouble. The blast will tend to break to the slips beyond the holes and tend to produce cutoff holes leaving unblasted ground. This type of ground usually produces many quite large slabs. Fractures and slips which tend to run parallel to the breaking face are particularly bothersome in this respect, causing continuous overbreak of large pieces, both in the horizontal systems and vertical systems. Rock structure works more or less the same way, the breaking angle depending on the rock strength. These parallel structures and slip factors can sometimes be taken advantage of in choosing a breaking system.

All the foregoing mine characteristics should be taken into consideration in determining whether the diamond-drill system is applicable to the ore body. Undoubtedly most of the mines reporting have done this as much as was possible at the time. Of course as mining goes on,

Vinton H. Clarke started his mining career in 1931, near his birthplace in British Columbia, by working his own placer deposit. Since that time he has dug in several holes from northwestern United States to Alaska. Immediately after receiving his degree in mining and metallurgy from the University of Washington in 1937, he went to work for the Howe Sound Co. at the Holden mine near Chelan, Wash. It was there that he came in contact with diamond-drill blasthole stoping; for the method was first experimented with and developed as the mining method of that property during his stay there. Since 1946, Mr. Clarke has been attached to the New York office of that Company and has made many trips into the field to study diamond-drill-stoping technique at various properties.

XUM

TABLE OF QUESTIONNAIRE RESULTS FROM SURVEY

		A	B	C	D	E	F
1 Type of deposit		Chert impregnated with s.	S.r.d. in beds of argillaceous sediments	S.r.d. in shear zone	Primary Cu-Ni s.d.	Au-Ag-Zn-Cu s.r.d. in echelon. Irreg. masses of dissem. Cu s in chlorite	Massive s.r.d., isolated blocks of pegmatite within ore zone
2 Size of vein or block	(Length)	200′	1 mile	150′	400′	300′	P. 15–30′ Off. 55–260′
	(Height)	90′	Unknown	150′	500′	200′	55′–90′
	(Vein thickness)	60′	Up to 265′	18′ aver. up to 50′	200–300′	10–180′	P. 8–20′ Off. 40–180′
3 Attitude	Dip	HW 87½ FW 87½	Above 3900, 17° Below 3900, 39°	85°	Above 1400, HW 15°, FW 50° 1400–1500, HW 90°, FW 90°	55°–90°	HW 35–90° FW 40–70°
	Walls reg., irreg.	Regular	Regular	Irregular	Irregular	Irregular	Regular
4 Type of wall rock	HW	Indurated sandstone	Thin bedded sediments	Sericite schist	Granite breccia	Quartz porph. or massive andesite	Basic hornblende gneiss
	FW	Slates	Chert	Sericite schist	Gneissic granite complex	Quartz porph. or massive andesite	Gneissic quartzite
Will blasthole break to definite wall	HW	Yes	Yes	No	No	Yes	P. & reg. stopes, Yes Off., No
	FW	No	Yes	Sometimes	No	No	As above
Does wall cave or slough	HW	No	Slightly	Somewhat	Slightly	Yes	No
	FW	No	No	No	No	Yes	No
5 Ore breaking qualities a. To line of holes		Yes	Vert. rings—Yes	Yes	Yes	Yes	Yes
b. Beyond line of holes		No	....	No	No	....	No
c. Break to slips or fractures		Horiz. heads affect fragmentation	Horiz. rings—Yes	No	No	No	No
6 Method of mining used		Aldermac	Noranda Horiz. rings from raises, Horiz. holes from slots	Noranda Horiz. holes from slots	Noranda	Noranda, Aldermac Horizontal holes	Aldermac mainly
7 Type of ore, i.e., high sulphide content, highly siliceous		Highly siliceous	High sulphide	High sulphide	30% sulphide 70% granite breccia	High sulphide	High sulphide
8 Ore drillability, ipm, preferably using a. 3″ Leyner @ 85ℓ press., 1¾″–4-wing bit used on starter		6 ipm	18–20 ipm	3½″ Leyner @ 90ℓ press. 15–20 ipm	9 ipm	3½″ Leyner 1 15/16″ bit 12 ipm	4″ Leyner 90ℓ press. 1⅝″ bit 26⅔ ipm
b. With air driven diamond drill in good condition, preferably using a light machine of 160–180ℓ wt. @ 85ℓ press., EXE size bit		1¾″ coring bit 2½ ipm	1 3/16″ cast set concave plug bit used with TNT drill weighing 200ℓ, 80ℓ press. 13 ipm	....	Coring bit 6 ipm	Bit & machine as below 4.4 ipm	1½″ coring bit 6–12 ipm
9 Type of machine used c. Manufacturer		Boyles Bros.	Intern'l Multi-feed Drills	Boyles Bros.	Canadian Pneumatic	Longyear (3420)	Boyles Bros. (C.P. 5)
b. Total weight		....	200ℓ	J.V.	160ℓ	130ℓ	295ℓ, 160ℓ
c. Best speed for ground (RPM @ bit)		3300 RPM	1800 RPM	....	1500	3000	3000
d. Power		Air	Air	....	Air	Air	Air
10 Rod length		10 ft	30 in.	5 ft	2 & 5 ft	2 ft	1½ ft
11 Type of bit used a. Manufacturer		Mineral Drillers, Ltd.	T. Connors Diamond Drilling Co.	Truco	Inco	Truco	Boyles Bros., J. K. Smit, Truco
b. Type		Cast set coring	Cast set concave plug	Coring	Coring	Pilot blasthole, 84% Coring, 16%	Coring
c. Size		2″ (Size B)	1 3/16″	1½″	1½″	1½″	1½″
12 Feet drilled per bit		Not known	80 ft	....	43 ft	Pilot, 362 ft Coring, 248 ft	48 ft
13 Diamond recovery		70%	6¢/foot	....	46%	72%	55%
14 Tons broken per ft drilled		6	2.7	....	2.3	3.6	P. 1.85 Off. 3.75–5.0
15 Feet drilled per machine-shift		17′	93′	....	70′	104′	48.5
16 Ft drilled/man-shift (Total d-d crew)		8.5′	46.5′	....	70′	52′	25.4
17 Tons broken per machine-shift		Not known	250	....	161	375	P. 50 Off. 150
18 Tons broken per man-shift		Not known	125	....	161	187.5	P. 25 Off. 100

Note: a.—sulphides; r.—replacement; d.—deposit; porph.—porphyry; P.—pillars; Off.—offshoots; bdc—buildose chamber.

ON DIAMOND DRILL BLASTHOLE STOPING METHODS

G	H	I_1	I_2	I_3	J	K	L
Massive s.d. Chalcopyrite & sphalerite	Quartz-s. bodies along shear zone. Chalcopyrite, sphalerite, Au	Siliceous r. in tuffs with heavy Zn & Cu s.	Siliceous r. in tuffs with moderate Cu s.	Siliceous r. in quartz chlorite schist with dissem. Cu s.	High calcium limestone	Syenite porph. with quartz & calcite filled fractures. Minersl-Au	Tabular conglomerate bed 75°N dip. Mineral-Au
180′	200′	100′	100′	110′	....	80′	150′
160′	275′	160′	160′	200′	....	175′	50′
100–140′	15–100′	30′	40′	50′	40–70′	30′	35′
HW 68° FW 77°	HW 65–70° FW 65–70°	HW 70° FW 70°	HW 70° FW 70°	HW 70° FW 70°	HW 52–90° FW 52–90°	HW 65–70° FW 65–70°	HW 75° FW 75°
Regular	Irregular	Regular	Irregular	Regular	Regular	Slightly irreg.	Regular
Graywacke	Biotite schist	Moderately fissile tuffs	Siliceous	Quartz chlorite sericite schist	Thin shaly ledge, thin impure limestone	Arkose	Slate
Schist & graywacke	Quartz biotite, amphibole schist	Moderately fissile tuffs	Siliceous	Soft slates & anhydrite	Parting seam, then imp. limestone	Arkose	Slate or graywacke
No	No	Yes	No	Yes	Yes	Yes	Yes
Yes	No	Yes	No	Yes	Yes	No	Yes
Yes	Yes	Yes	No	Yes	No	Yes	Yes
No	No	Yes	No	Yes	No	No	No
Yes	Yes	....	....	....	Yes	Yes	Yes
No	Occasionally	Yes	No	Yes	No	Occasionally	No
Yes	Seldom	Yes	Yes	Yes	Yes	Yes	Somewhat
Noranda down-up	Noranda down only	Horiz. holes from slots parallel	Horiz. holes from slots parallel	Noranda down-up. Aldermac, horiz. holes from raises fanned	Horiz. holes from slots & variation	Horiz. holes from raises fanned, used in floor pillars. Up holes in parallel rings for stope sills	Noranda down-up rings drilled radially from central subdrift
High sulphide	10–30% sulphide	Highly siliceous	Highly siliceous	Moderately siliceous	High calcium limestone	Fairly siliceous	Moderately siliceous
10–18 ipm	6–8 ipm	7½ ipm	....	....	14 ipm	3½″ Leyner 5½ ipm	1⅝″ bit 9 ipm
18–24 ipm	3 ipm	....	90ƒ air press. 1¼ ipm	3½ ipm	12 ipm	Boyles JV-290ƒ 1⅝″ bit 5 ipm	210ƒ machine 10 ipm
Sullivan	Boyles Bros. C.P.5.ƒ-U	Boyles Bros. (JV)	Boyles Bros. (JV)	Boyles Bros. (JV)	Sullivan	Boyles Bros.	Boyles Bros.
160ƒ	165ƒ, 435ƒ	240ƒ	....	....	165ƒ	290ƒ	210ƒ
3500	1200–1500	2800	....	....	3300	2000	3000
Air	Air	Air	....	....	Air	Air	Air
2 ft	1, 2, 2½, 3, 5 ft	6 ft	....	....	5 ft	5 & 10 ft	....
Christensen	Christensen	Boyles Bros.	....	....	Truco mostly	Boyles Bros.	Boyles Bros.
Concave plug	Coring	Concave plug	....	....	Concave plug & pilot	Powd. metal & cast set bits	Round faced powd. metal
1½″	1 15/16″	1½″	....	....	1 7/16″	1⅜″	1⅜″
105.8 ft	10–30 ft	25.2 ft	25.2 ft	31.0	3,000	PM 43.0 Cast 26.5	52 ft
63%	65–75%	71.3% average	71.3% average	71.3% average	....	60–70%	40%
2.5–2.65	7–8	2.78	2.78	5.75	5.0	3.2	1.4
127.3	27	45.5	45.5	48.2	100.0	40.0	40–50
127.3	23	22.75	22.75	24.1	50.0	40.0	40–50
300	160	126.5	126.5	277.0	190.0	125.0	65
300	140	63.25	63.25	138.5	95.0	125.0	65

TABLE CONTINUED . . .

	A	B	C	D	E	F
19 Type of explosive used a. Size	1¾" x 10"	1⅛" x 8"	1⅛" x 8"	1¼" x 8"	1¼" x 8"	(a) 1¼" x 8" (b) 1⅛" x 8"
b. Speed	Not known	17,000 fps	....	17,000 fps	(a) 14,500 fps (b) 10,000 fps	(a) 16,000 fps (b) 14,000 fps
c. Type	75% gel.	amm. gel.	40% & 75% amm. gel.	75% amm. gel.	(a) Polarforcite, 40% (b) Stopite, 55%	amm. gel.
20 Loading a. Are spacers used	No	No	No	1-18" sp. 6' from collar	No	No
b. Is tamping used	Top & bottom of hole with clay	No	Yes	Yes	No	Yes
c. Where is primer placed	....	Collar + 6' or second to last stick	Collar + 6'	Collar + 6'	Second stick from end of hole	....
d. Detonation	Primacord	Electric, 20% Primacord, 80%	Electric	Electric	Elec., under 20' Primacord, over 20'	Primacord
e. Percent of hole loaded	90	92	100	95	50–100	Ring drilling 90 Panel 100
f. Pounds of powder per loader shift	....	....	....	210	500	....
g. Pounds of powder per ton	0.37	0.17	0.33	0.28	0.15–0.32	P. 0.5 Off. 0.3
h. Pounds of powder per ft of hole	2.22	0.48	1.00	0.64	....	1.0
i. Is pattern & spacing of holes determined by the amount of powder you wish to use to break ore	Unknown	No	Yes	Yes	Yes	No
21 Length of holes a. Longest	90'	150	75'	95'	110'	170'
b. Shortest	90'	6'	....	20'	10–12'	9'
c. Average	90'	60'	40'	60'	50–60'	60'
22 Bonus system a. Used in diamond drilling	10s per shift	Yes	20¢/foot	Yes, varying with % of sulphides	Yes	Yes
b. Used in loading	....	No	No	No	Yes	No
c. Used in drawing	¼ per ton	Yes	On tot. ton. from mine	No	Yes	Yes
d. Is diamond loss a factor in calculating bonus	No	No	No	No. Penalty if bit abused	Yes	Yes
23 Size of broken ore a. Largest	3000 T	7 ft	1000 cu ft	2000 cu ft	200 + cu ft	500 cu ft
b. Average	Unknown	6 cu ft	8 cu ft	25 cu ft	3 cu ft	8 cu ft
24 Drawing a. Draw holes	8' x 8' to bdc	To bdc's & slusher drifts	....	....	Mainly to slusher drifts	To bdc's
b. Chutes	....	3' x 5'	....	3.5' x 5.0'	....	....
25 Secondary breaking a. Method	100% mud capping	10% mud capping; 90% drilling & blasting	Drilling	Mud capping	Mud capping & drilling	50% mud capping; 50% drilling
b. Explosives used per ton drawn	Unknown	....	0.20	0.26	....	....
26 Why was d-d blasthole system originally used a. Manpower shortage	Yes	....	....	....	....	....
b. Safety reasons	....	Yes	Yes	....	Yes	Yes
c. More economical	Yes	Yes	....	Yes	Yes	In off. stopes
d. Could not be mined otherwise	....	For pillars	Yes	....	....	....
e. Other reasons	....	....	....	....	More flexibility	....
27 Do you feel present method is best for your ore body	....	Yes	Pillars—yes Vein—no	Yes	Yes	Yes
28 If not, would you change to another d-d method	....	....	No	....	....	....
29 If not, would you change to another mining method	....	....	Yes	....	....	....
30 If not, are you now changing methods or do you contemplate changing to non-d-d method	....	No	....	....	....	....
31 Have you already changed over and, if so, what method are you now using	Changed in 1946 to underhand sublevel stoping with percussion drills	....	....	....	....	....
32 Have costs proved to be better in your method in answer to question 31	Yes	....	....	....	....	....
33 Have costs proved to be better for the d-d system over those for a system formerly used (assuming labor and supply costs were to remain the same)	....	Not comparable due to changing mining conditions	No	Yes	Yes	Off. stopes have not been mined any other way
34 Have you experimented with tungsten carbide bits in blasthole work	No	No	No	No	No	No
35 If so, how long a hole can you successfully drill	....	....	....	....	....	....
36 If so, does the cost picture look promising at present price of bits	....	....	....	....	....	....
37 What price would be necessary to make their use possible	....	....	....	....	....	....

G	H	I_1	I_2	I_3	J	K	L
1¼" x 12"	1¼" x 12"	1" x 8"	....	....	1½" x 8"	1½" x 8"	1½" x 8"
16,500 fps	20,000 fps	17,000 fps	....	....	13,000 fps	18,800 fps	17,000 fps
amm. gel.	60% gel.	75% amm. gel.	....	....	60% gel.	60% gel.	75% gel.
No	No	No	....	....	No	No	No
Yes	Yes	No	....	....	No	No	Yes
....	Collar + 10'	Collar + 6'	....	....	Center	Collar + 7 to 8'	Collar + 2 to 13'
Primacord	Electric	Electric	....	....	Electric	Electric	Electric
80	95	90–95	....	....	95	96	95
432	700–800	250	....	....	....	250	370
0.12	0.21	0.29	0.29	0.12	0.20	0.22 to 0.25	0.44
0.60	1.51	0.85	0.85	0.85	0.70	0.63	0.635
No	Yes	No	No	No	Yes	Yes	Yes
92'	100'	100'	100'	100'	150'	100'	65'
14'	15'	20'	20'	20'	40'	10'	8'
55'	50'	65'	65'	65'	90'	42'	28'
Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Yes	Yes	No	No	No	....	No	Yes
Yes	Yes	No	No	No	....	Yes	Yes
No	No	No	No	No	....	Only if damaged	No
....	120 cu ft	....	....	2250 cu ft	64 cu ft	600 cu ft	125 cu ft
....	4 cu ft	....	....	18 cu ft	8 cu ft	8 cu ft	1 cu ft
To slusher drifts	6'x9' draw holes to slusher drifts	....	....	To bdc's & slusher drifts	To bdc's	To bdc's	To bdc's
....	....	....	....	....	6' x 6'	36" x 38"	....
10% mud capping; 90% drilling	Mud capping	....	....	75% mud capping; 25% drilling	20% mud capping; 80% drilling	20% mud capping; 80% drilling	25% mud capping; 75% drilling
0.35	1.30	0.33	0.33	0.50	0.20	0.50	0.256
....	Yes	Yes	Yes	Yes	....	....	Yes
Yes	Yes	Yes	Yes	Yes	Yes	....	....
....	....	....	....	Yes	Slightly	....	....
....	....	....	....	In some places	....	For pillars	Partially
....	....	....	....	....	....	....	....
Yes	Yes—at present	No	Yes	Yes	Yes	....	No
....	....	....	....	....	....	....	No
....	....	....	....	....	....	....	Yes
....	....	....	....	....	....	....	Now beginning to change
....	....	....	....	....	....	....	Percussion drills
....	....	....	....	....	....	....	Insufficient data
Yes	....	....	....	Yes in section where horisontal rings used	Yes	....	....
No	Yes	.....Preliminary testing only.....			Yes	No	No
....	35 ft	.....30 ft.....			2 ft?	....	....
....	Yes	.....Yes, about 50% less.....			No	....	....
....	....	....	....	....	....	....	....

COST FIGURES OF DIAMOND-DRILL BLASTHOLE STOPING METHODS

		C	D	F*	G	H	I_2	K*	L*
38	**COSTS—Ore breaking**								
	a. Feet drilled	.....	18,218	6,076	2,701 (one slice)	27,929	39,324	48,167	18,281
	b. Tons broken by above footage	.....	41,700	11,206	7,100	193,560	183,663	154,100	25,900
	c. Drill site prep./ft. (includes drift cleaning, raise platforms, etc.)	.....	0.6¢	.....	.....	8.1¢	5.0¢	.....	0.4¢
	d. Drilling labor per foot	.....	17.0¢	55.0¢	14.1¢	54.1¢	78.0¢	33.1¢	26.7¢
	e. Drilling supplies per foot	.....	1.4¢	1.7¢	9.3¢	16.2¢	4.0¢	5.0¢	no data
	f. Drilling supervision per foot	.....	3.0¢	2.3¢	.....	16.8¢	8.0¢	7.9¢	no data
	g. Drilling repairs per foot	.....	1.7¢	9.5¢	1.2¢	18.4¢	8.0¢	1.1¢	no data
	h. Drilling bits per foot	.....	29.1¢	34.5¢	29.9¢	126.7¢	74.0¢	44.9¢	36.4¢
	i. Total (c-h) items per foot	.....	52.8¢	102.9¢	54.5¢	240.3¢	177.0¢	92.0¢	80.4¢
	j. Total (c-h) items per ton	.....	23.1¢	55.8¢	20.7¢	53.0¢	38.0¢	28.8¢	57.0¢
	k. Compressed air per foot	.....	2.5¢	4.3¢	6.2¢	9.4¢	9.0¢	7.5¢	no data
	l. Loading and blasting labor per foot	.....	2.8¢	3.3¢	1.6¢	11.0¢	7.0¢	2.8¢	1.1¢
	m. Explosives per foot	.....	10.6¢	9.5¢	5.1¢	20.4¢	13.0¢	12.0¢	9.3¢
	n. Supplies per foot	.....	0.9¢	4.0¢	.....	1.1¢	4.0¢	.....	no data
	o. Total (k-n) per foot	.....	16.8¢	21.1¢	12.9¢	41.9¢	33.0¢	22.3¢	.....
	p. Total (k-n) per ton	(j)+(p) 45¢/ton	7.3¢	11.5¢	4.9¢	9.2¢	7.0¢	7.0¢	.....
	q. Average d-d crew wage per shift	.....	$9.40	Runner $8.32 + bonus Helper 7.60 + bonus	$15.29 (incl. bonus)	$12.44 Runner 11.44 Appren. 10.94 Helper	$17.97 Runner & Helper	$9.30	$8.58
39	**COSTS—Ore drawing**								
	a. Labor per ton	.....	17.0¢	30.0¢	11.3¢	20.4¢	30.0¢	16.0¢	19.5¢
	b. Explosives per ton	.....	4.0¢	5.0¢	6.0¢	22.7¢	5.0¢	10.0¢	5.8¢
	c. Supplies per ton	.....	.....	4.5¢	0.7¢	6.1¢	10.0¢	.....	3.0¢
	d. Total costs per ton	.....	21.0¢	52.0¢	18.0¢	49.2¢	45.0¢	40.0¢	38.0¢ Above differences due to distributables
40	What were your ore breaking costs per ton for method of mining used previous to d-d method (at present day wages and supply costs)	35¢	40.0¢	115.0¢	29.6¢	68.6¢	.....	.....	.....
41	What are or will be your costs for new method after using d-d method (at present day wage and supply costs)	35¢/ton	.....	.....	.....	.....	.....	.....	.....
42	What were your ore drawing costs per ton before using d-d method (present day wages)	.....	19.5¢	45.0¢	33.4¢	32.3¢	.....	.....	.....
43	What are or will be your ore drawing costs per ton for new method (present day wages)	.....	.....	.....	.....	.....	.....	.....	.....

(K)* Note: Blastholes used for pillar recovery only. Last figures believed to be close estimates of direct break. Drawing costs do not pertain to blasthole muck only, as shrink and cave muck are drawn with it. (L) Note: No. 1 Stope 1947. (F) Note: Item 39d includes haulage costs.

new problems continuously crop up and varieties of the method are devised to meet them. Indeed, many of the breaking characteristics of the ore are not readily determinable until ore breaking in the stopes is well along.

Summing up the first six questions, it appears that diamond-drill blasthole mining can be and has been applied where the following conditions are present:

(1) Block width (length along strike) of 80-400 ft, with most between 150-200 ft. Wider stopes are mined, where possible, on upper levels, thus taking advantage of draw distribution. Pillars, tail end extractions, and isolated veins are of course exceptions.

(2) Block height of 50-500 ft with most between 150-200 ft.

(3) Vein thickness of over 30 ft is usually preferable.

(4) A steep dip is preferable—something over 55 degrees—although not entirely necessary. A flatter dip would present the same difficulties in other methods of mining. Note mine B's dip of 17 degrees above the 3900 and 39 degrees below the 3900. In general, 50 degrees is about the absolute minimum dip for free-running ore. At this angle there will be some difficulty in clearing the face for blasting following rings, especially in any vertical-ring system when a new stope is being opened. It is somewhat better using horizontal holes where the broken ore can be drawn quickly through several drawing points and where it does not pile up against the breaking face.

(5) Walls should be fairly regular, i.e., not turn more than 20 degrees in average ground when vertical rings are being used. Horizontal holes can be adapted easily to irregular walls by placing drilling raises at the bends, although here it is generally uneconomical to have to place them closer than about 120 ft apart, allowing a hole length of about 55-60 ft. Generally, there is little trouble in irregular walls where holes can be "dead-ended" into the hanging wall.

(6) Diamond-drill blasthole mining is nicely adapted to veins having well-defined hanging and footwalls, but this is by no means essential.

(7) Most walls will slough to a certain extent and some dilution must be expected.

The most important point in choosing a new mining method is the cost. If the d-d blasthole method is being considered one must know how much the cost will be per foot of hole drilled and how much per ton of ore broken by the foot of hole. What should the hole size be? What type of bit, what type of machine should be used? What size and grade of diamonds should be used? Some of these can be determined fairly easily by ordinary testing methods; others, such as the size of hole and hole spacing, probably will be determined only after much actual stoping experimentation. On the data sheets the performance data of many actual operations are shown indicating

the choice of methods and equipment chosen and the results obtained by many varied conditions of mining. A brief comment on each follows:

(1) *Ore drillability*—Speed of drilling with percussion drills varies from a minimum of 5½ in. per min in a fairly siliceous ore body to a maximum of 26½ ipm in a high sulphide ore body. In only two instances does the speed attained by diamond drills exceed that by the percussion drill used at the particular property. Conditions of drilling and equipment used of course are different, but the results indicate that, in general, percussion drilling is still usually faster than diamond drilling.

(2) *Type of machine used*—Many good machines are on the market today, most operators choosing light machines, under 200 lb in weight, that can be broken down easily and quickly for transportation and setting up. Maneuverability in lining up and changing rods are important factors in the choice of machines. All machines reported are air-powered. In general, those mines reporting the hardest drilling ground use a slow bit rotation or from 1200 to 2300 rpm. Mines having softer ores use up to 3500-rpm speeds.

(3) *Type of bits used*—Coring and plug bits are about evenly divided among the mines reporting, some using cast set bits and others metal powder bits. Size of bits ranges from 1 3/16 to 2 in., with the greatest number of mines using the 1½-in. size or close to it.

(4) *Bit performance*—The number of feet drilled per bit varies from 10 to 30 ft for a 1 15/16-in. coring bit in hard ground to 362 ft for a 1½-in. pilot-type bit in high sulphide ore. In a limestone mine, up to 3000 ft has been obtained from a 1 7/16-in. concave plug bit. Diamond recovery ranges from 40 to 75 per cent. High diamond recovery does not necessarily mean low diamond cost, as shown by the cost data. Probably those mines obtaining high diamond recovery are using a larger and better grade of stone. Some of the properties showing low diamond recovery are obtaining excellent bit costs and are probably using small, low-grade stones.

(5) *Ore breaking performance*—Tons broken per foot of hole vary from 1.85 in pillar breaking to 14 in stoping. Determination of the number of tons of ore to be broken by a foot of hole depends on an economic balance between primary and secondary breaking. By decreasing the tons per foot figure, the fragmentation should improve, thus decreasing the secondary breaking cost. But to what point can one afford to increase the primary breaking cost? Each mine must determine this by constant experimentation and observation of results. Such factors as caving and overbreak must be taken into consideration, for where these conditions exist it is nearly useless to decrease the tons-per-foot figure too much. To obtain the greatest breaking efficiency, each mine must decide what size hole will be the most economical. Most operating properties know how much explosive is necessary to break the ore to the desired size. Perhaps a larger hole spaced so that the known powder charge per ton will be obtained will show a lower over-all cost. In other words we are now comparing the costs per cubic inch of hole drilled. Perhaps a 2-in. hole can be drilled cheaper per cubic inch than a 1½-in. hole, or perhaps a size between these two or even over 2 in. will be more economical. This statement is made because an examination of the tabulation sheets indicates a preponderance of sizes close to 1½ in. Has this choice been due to testing, or custom?

The feet drilled and tons broken per man-shift indicate that in some states and provinces two men must work together on a machine, probably necessary by law. Performance is then down considerably and the problem would seem to be to increase efficiency by providing productive work for the second man or helper. One method is to place two machines together, which is probably done wherever possible. Consideration of a larger hole fits into this situation as the larger rods would probably require a two-man crew anyway.

Most operators seem to prefer a fast explosive for primary breaking, i.e., over 16,000 fps. The speed of powder to produce the best results must be determined by trial and error. As a general rule, hard, brittle ore requires a fast powder to give good fragmentation, and a soft ore, a slow speed powder which will produce more of a heaving action. Much back break and waste of explosive energy can result from the improper choice of explosive. High speed powder has sometimes been used to ensure complete detonation where electric primers were placed at or near the collar of the holes. Other mines have used slower powder and obtained complete detonation by moving the primer down the hole farther, or by using Primacord. Most operators seem to prefer the short 8-in. stick, no doubt feeling that it can be tamped more easily and completely. In the question, "Is tamping used," it is not known how many operators interpreted it to be the use of "stemming," or whether they had in mind the mechanical operation of squeezing the powder tight within the hole; so answers are valueless. Practically all mines charge the hole solidly with explosives, leaving only a short length of hole near the collar unloaded. About one half the mines calculate the explosive charge they wish to use to break the ore, then space the holes accordingly. Diamond-drill blastholes are drilled up to 170 ft long, but the average is close to 60 ft.

(6) *Bonus systems*—All mines reporting, but one, indicate that some form of bonus system is used in diamond drilling. Most are not in favor of tying the rate to any form of diamond loss. One difficulty experienced has been due to the usual long time interval necessary for actual determination of diamond loss and the resultant bonus lag. Other difficulties are due to variations in the ore, some sections drilling easier than others. Two operators report that penalties are imposed on drillers upon evidence of bit abuse. Our experience has been that diamond-drilling bonuses are subject to much arbitrary judgment and their success is largely dependent on the man in charge. Only a few mines have put loading on a bonus basis, probably owing to its importance in the success of the whole cycle. About half the mines have placed ore drawing on bonus.

(7) *Ore drawing*—Where diamond-drill blastholes are used they have for the most part replaced percussion drilling. They have, however, also replaced the old mining method of powder blasting with coyote holes. As a result there has been some change in fragmentation of the ore

broken. Fragmentation has generally been coarser with the larger area of stope face made possible by the longer holes. In comparing blasthole-broken ore with that obtained by powder blasting evidence indicates a higher percentage of fines by the powder blast method, but at the same time more coarse material also. The blasthole muck is generally more evenly sized.

As expected, different types of ore show great variation in the size of ore broken, the largest pieces being too large to pass through ordinary draw holes without secondary breaking. Usually the average sizes must also be broken still further in bulldoze chambers or slusher drifts to pass through grizzlies. The amount of secondary breaking to be done in the drawing operation is, as mentioned before, directly dependent on the spacing of holes, explosives, and burden used in the primary-breaking operation, slabbing and caving discounted of course. It is generally conceded that successful drawing of ore and subsequent transportation is dependent on steady smooth flow to the mill. The sensible trend would then seem to be in the direction of eliminating chutes, increasing the size of mine cars to the point where all or most of the ore that flows through the draw holes of its own free will can be loaded directly into the car. Handling this larger ore will of course require larger crushers underground. Eliminating ore pockets, chutes, and skips by substituting conveyor-belt haulage is another step toward smooth, continuous flow in drawing and transportation. Of course size of operation is all-important in the consideration of these steps as all mean higher capital investment which can be much more easily amortized by high tonnage mines. We are perhaps departing a little from the subject at hand, but we believe the foregoing illustrates the importance of ore drawing and ore breaking in the mining operation.

The mines reporting are about evenly divided in their methods between drawing to bulldoze chambers and drawing to slusher drifts. The advantage of the former is that more tonnage per day can be drawn from a limited length of stope as more men can be put to work in this area, bulldozing chambers being placed on approximately 40-ft centers. In general, more tons per man-shift can be obtained from slusher drifts. In addition to this the operation is safer, development is less, and ventilation is better.

In secondary breaking, mud capping and drilling are used about equally among the mines. Generally when mud capping is employed it is used for the following reasons:

(1) Rock to be broken is inaccessible for drill.
(2) Ore breaks easily.
(3) Shortage of man power and drawing places.
(4) Increase in explosives' cost by this method is less than extra labor and supplies necessary for drilling method.

(8) *Costs*—Any discussion of the costs shown on the tabulation sheet would be superfluous, but examination by each individual operator and application of his findings to his own situation may prove of much value to him.

In an attempt to evaluate the present methods of d-d blasthole mining some rather searching questions were asked, such as: Why was the diamond-drill blasthole system originally used? In following the answers across the chart the reason given by most mines reporting is safety; it is apparently the dominating factor in the choice of this method by those mines. Running neck and neck for second place are the two items of man-power shortage and economics. In the early days of the war when labor became short, many operators could see more tons per man-shift being broken by diamond drills than by percussion drills or by other methods. They could also see it replacing hundreds of feet of development drifts and raises, which also took man power. Some changed to blasthole drilling chiefly because the tonnage had to be maintained, not necessarily because this method was cheaper than the one formerly used. Another group of operators chose the method because it would prove to be more economical than the method formerly used. Both of these groups also said the method was chosen because of safety reasons. But the fact that the safety reason appears nearly across the board does not necessarily mean that it is the all-important factor. On the other hand it has probably been secondary in importance to the man power and economic factors—still important, indeed, but usually only a contributing reason for change.

Several mines have mentioned that an important reason for adopting d-d blasthole mining has been to recover pillars which could not be recovered otherwise. Other important reasons for adoption have been for greater flexibility and sometimes less dilution from shattered walls as mentioned earlier in this article.

Most operators feel that their present d-d blasthole methods are the best for their ore bodies. Therefore, at least at the present time, most operators seem satisfied with results; they like the method of mining for many reasons, chiefly we believe, because it has pulled many out of tight spots from the production angle during difficult periods during and after the war. Also, a great deal of credit must be given this method for bringing to some mines a degree of safety never attained before. It certainly is a great comfort to both miner and management to be able to stand off at a safe comfortable distance from an open stope and literally slice off the ore with a ten-ft pole. The method has made it easier to recover pillars and odd pieces of ore along the fringe of old stopes. The method is flexible and sometimes cuts down on dilution. This then is the present status of the d-d blasthole method of mining—a method well liked by the operators. Now there is only one fly in the ointment: costs are going up—wages, supplies, diamond costs, etc. With this in mind several questions were asked regarding new methods.

Two mines have changed back to the use of percussion drills with conventional steel. The only other change lies in the possible use of tungsten carbide bits with percussion drills to replace diamond drills in ore breaking. This has been tried in three mines and with great success in two of them. On the tabulation sheet, one mine reports attainment of a length of 35 ft and the other 20 ft at half the cost of the equivalent footage drilled by diamond drills. This is certainly something to open an operator's eyes. Of course 20 ft and 35 ft are nothing like the 55 to 60 ft and even sometimes greater footages required for some holes, but there is no reason to believe that with

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time and further research these lengths cannot be attained with the percussion drill equipped with a tungsten carbide bit. Even lengths of 20 and 35 ft will cover 20 to 30 per cent of most drilling patterns. Recent information from one mine is that holes are now being successfully drilled up to 65 ft in length with 4-in. Leyners.

However, what proves to be a distinct advantage in one type of rock does not necessarily mean it will be equally so in another. Further news on this new development will be eagerly awaited, and as more operators begin research work a clearer picture should develop fairly soon to prove the actual value to the operator. However, drilling with percussion drills and tungsten carbide bits need not change any part of the mining method. Development would remain the same and drilling patterns would be identical. The only difference would be in the actual physical and mechanical operation of the percussion drill with extension steel, compared with the diamond drill. Tungsten-carbide bits have had some difficulty competing with regular drill bits, but perhaps they will make a much better showing against diamond bits.

The future possibilities of the d-d blasthole method then, possibly do not lie with diamond drills at all, but rather back to the percussion drill. This of course depends on a comparison of drilling costs and must be determined at each individual mine, taking into consideration the future possibility of fluctuating diamond costs and tungsten-carbide bit costs. Another bit development for drilling long holes which has proved quite successful in certain types of ground is the application of an acetylene tube borium bead[2] to the cutting edges and reaming corners of standard rock bits. Costs in oil shale using these bits with percussion drills have been materially below those possible with either tungsten carbide bits or diamond bits. Some work has been done with small pieces of tungsten carbide set in diamond bit blanks. This has been done to take advantage of the favorable characteristics of the rotary type drill.

Getting back to appraising the future of the method it seems safe to say that techniques have been developed to the point where efficient, safe ore breaking can be accomplished, and that it will continue in the future. Whether diamond drills will continue in their present favorable capacity is a direct function of the cost. Nothing on the immediate horizon justifies the thought that commercial diamonds will decrease in price. Indeed will any form of supplies? Man-power supply still remains critical in most areas and the method will still remain attractive from this angle. High tons per man-shift broken safely at low cost will always be a great selling point for any mining method.

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[1] Idarado Mine, Ouray, Colo. Reported by K. H. Fox, *Explosives Engineer*, March-April 1948.

[2] Tell Ertl, John R. Wagner, Jr., and Ernest E. Burgh, "The Development of a Successful Hard Surfaced Bit for Drilling Oil Shale." Presented before the 75th Anniversary Meeting of the AIME in New York, 1947.

Private Enterprise for Tin

The only privately-owned tin smelting plant in the United States is now being erected by the Vulcan Detinning Co., at Sewaren, N. J. The new smelter, which will cost about $400,000, is expected to produce, initially, five tons of refined tin a day, by using a newly developed extraction process on low grade Bolivian concentrates. Heretofore, such a process was considered commercially impractical.

Oxygen Plant for Coal Gasification

The first tonnage oxygen plant for use in coal gasification is now operating at the coal-to-oil demonstration plants of the Bureau of Mines, at Louisiana, Mo. The plant is a modern Linde-Fränkl unit that was originally used by the I. G. Farbenindustrie to make chemicals, at Hochst, Germany. Recently though, it was dismantled and shipped to the United States complete, save for building, piping, and other materials available here. The Bureau is using this Linde-Fränkl unit as a means of evaluating the cost of oxygen in the production of synthetic oil and gasoline from coal.

Scholarship in Memoriam

The Charles A. Grimes Memorial Scholarship was recently established at the Colorado School of Mines to provide a worthy boy, desirous of attending the School, with a thousand dollars a year for four years. The recipient is chosen on the basis of financial need and scholastic ability, regardless of his race, creed, or color. Charles A. Grimes, to whom the scholarship is dedicated, was a 1940 graduate of the School who lost his life while serving with the U. S. Army Air Forces during the war. The award bearing his name was made possible by a grant from his family.

Diamond Bit and Reaming Shell Dimensions Standardized

Standardization of equipment has long been an urgent need of the diamond drilling industry, and, in 1946, the Diamond Core Drill Manufacturers Assn. appointed a technical committee to recommend standard sizes of diamond drilling equipment. After a thorough study of field conditions and users' requirements throughout the mining field, the technical committee has recommended the coring bit and reaming shell dimensions as set forth in the table. These standards have been approved by the Diamond Core Drill Manufacturers Assn. and are now in general use. These dimensions supersede all previously published dimensions and standards.

Approved dimensions for core bit and reaming shell sizes larger than NX, and for casing bits and casing shoes, will be published in subsequent issues. Further copies of all published DCDMA standards may be obtained from the Secretary, C. C. Rohrbach, at 90 West St., New York 6.

Table of Standards for Diamond Bits and Reaming Shells

Size	Core Diameter Nominal	Hole Diameter Nominal
EX	⅞"	1½
AX	1 3/16	1⅞
BX	1⅝	2⅜
NX	2⅛	3

Size	Set Bit I.D.	Set Bit O.D.	Set Reaming Shell O.D.
EX	.845	1.460	1.485
AX	1.185	1.865	1.890
BX	1.655	2.330	2.360
NX	2.155	2.945	2.980

Manufacturers tolerances in the USA are ± .005 in. from above set dimensions.

XUM

Timber Treatment Cuts Costs

cze preservative used at Homer mine

BY R. C. MAHON • HANNA IRON ORE CO., IRON RIVER, MICH.; MEMBER, AIME

During the early history of the Lake Superior district, tamarack timber was used almost exclusively in the mines. It had the strength and lasting qualities necessary for a satisfactory mining timber. But about fifteen years ago the tamarack trees were attacked by a blight which killed nearly all of them so today no tamarack timber is available. Hemlock, spruce, and poplar have neither the necessary strength nor the lasting qualities for mining timber, but a large supply of maple and birch is available. These have ample strength but, when placed underground, fail by decay in about three years. This means that, instead of replacing the timber sets once in fifteen years, it must be done five or more times in the same space of time, which involves not only increased timber costs but, more important, an increased labor cost. In addition, these decaying timbers present an increased hazard to the operation and safety of the mine. In 1945, on two occasions, a number of sets failed simultaneously in two different locations. Either failure could have caused a loss of life or serious accident; fortunately they did not, but each did result in a loss of more than $1,000 in production.

facts leading to adoption of treated timber

Following these failures the problem of the use of treated timber was investigated, and the following facts determined:

(1) From data obtained from the Du Pont Chemical Co. and from the Wisconsin Forest Products Laboratory, it was evident that one could expect a life of fifteen years for chromated-zinc-chloride-treated hardwood timber. This fact was substantiated at the Eureka mine of the Castile Mining Co. where timber so treated has been in use for over eight years.

(2) Chromated zinc chloride should be used instead of any type of creosote preservative. The preserving qualities of the two are comparable but the czc-treated timbers will not burn the hands of the men handling them.

(3) A considerable saving in main-drift timbering costs would result. The cost of a set of untreated timber, including framing and handling, is $4.50, a treated set costs $2.50 more, and the labor cost of placing a set of main-drift timber is $7. Over a period of fifteen years, using untreated timber, the cost per set, including replacements, would be approximately $57.50, whereas over the same period of time the cost of treated timber would be about $14 per set.

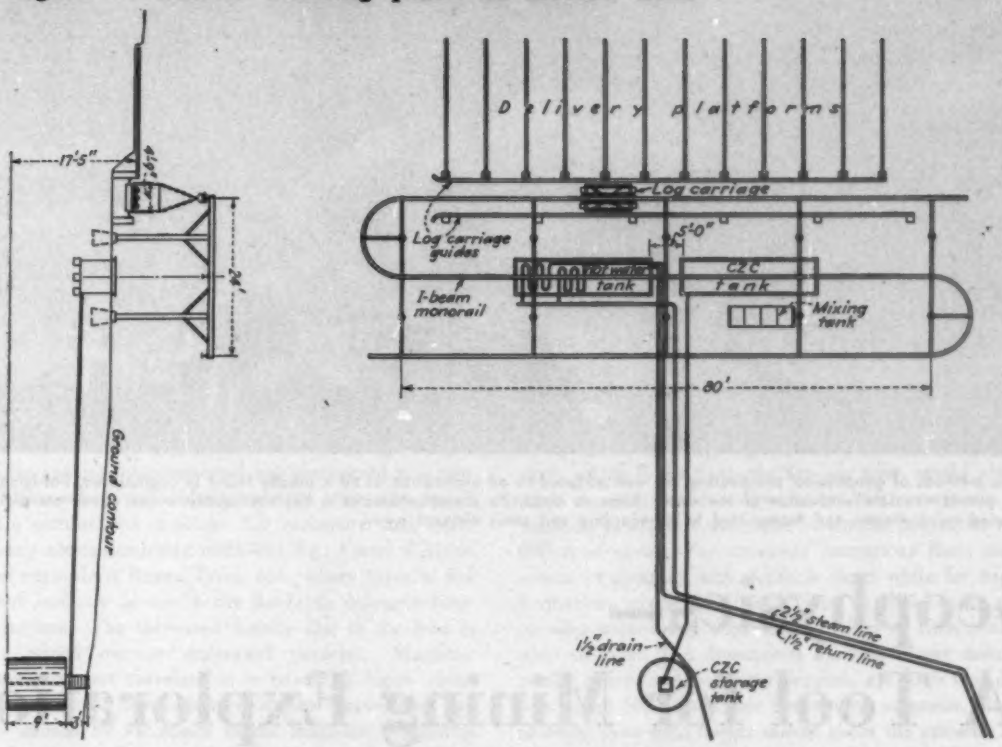
Courtesy U. S. Bureau of Mines

View of the timber treatment plant at the Homer mine of the M. A. Hanna Co. shows a supply of treated timber, treatment tanks, and the log carriage.

process of treatment

The timber is cut in March and April, when it peels easily. It is allowed to dry until September, by which time cracks have appeared along the length of the logs. These cracks are important as they create avenues through which the preserving solution travels into the annular rings of the timbers. The timber is then cut

layout of timber treating plant at Homer mine



The general layout of the plant is shown in the sketch. Steel bents support the I-beam monorail and are arranged so that the timber can be transported from the receiving platforms to the tanks and thence to the delivery platforms. Ample room is allowed at the end of the tanks to place the covers when they are taken off the tanks. The mixing tank is placed as close as possible to the czc tank. The circular storage tank is placed entirely below ground so that when the czc solution is drained into it for winter storage it will not freeze, and it is placed low enough to allow the czc to drain into it by gravity. Czc solution is returned to its tank from storage by air pressure. The hot-water tank is placed in a concrete pit to provide access to the piping and to protect the insulation of the tank. As the covers on this tank are also insulated, little heat is lost. Provision is made to drain this hot water into the mine sewer. The czc tank is similar to the hot-water tank but has no heating coils; it is placed in the ground on a concrete foundation. Eight-inch pipe columns are made of used pipe and are filled with concrete to support the monorail. The log carriages are especially constructed for easy loading and unloading of the timber. Raising, lowering, and transporting these cradles is done by a three-ton Yale-King cable hoist, electrically operated and remotely controlled.

to proper length and framed before processing, as any cut made after treatment would be a place at which decay might start.

The first step is to place the logs in the cradles, which are then lowered into the hot-water tank, the temperature of which is maintained as close to 210F as possible. The higher it is, the greater the penetration of the czc in the next step of the process. Timbers are left *covered* in this tank for twelve hours, which opens the pores in the wood.

Next the timbers are transferred to the czc tank, which contains a 10 per cent solution of chromated zinc chloride, where they are left for twelve hours by which time the czc solution has penetrated approximately 1½ to 3½ in. To get this penetration the timber must absorb not less than 0.75 lb of czc per cu ft. The penetration is checked by taking samples with an increment-borer and spraying them with iodine-potassium ferricyanide (starch solution). This test solution colors that portion of the bore penetrated by the czc.

After removal from the czc solution, the timbers are transported to the delivery platform, and allowed to dry for at least a month before using, by which time they have returned to almost their original weight.

Two tanks will accommodate any timber to be used at our mines, including main-drift and shaft timbers as well as other construction material. It is an ideal plant for a small mine, but, to treat timber on a larger scale, a pressure plant would give better results. From the interest that has been shown by other mining companies in our timber-treating plant, it is evident that preservation of mine timber in the Lake Superior district is going to be of increasing importance.

XUM

Seismic methods of geophysical prospecting are well adapted to oil exploration as oil is usually found in unglaciated, flat-lying areas which permit accurate evaluation of the data. Here, a dynamite explosion creates a tiny earthquake whose waves are picked up by buried seismometers and transmitted to a recording unit some distance away.

Geophysics— A Tool for Mining Exploration

By A. A. BRANT • CONSULTING ENGINEER, TORONTO; MEMBER, AIME

Mining men, quite as exploration minded as petroleum interests, are in the position where most of the exposed crustal portions of the earth have been examined, where the demand for metals is high and likely to continue so, and yet where, perhaps, the tools fail for the economic exploration of many of the possible mineral areas more deeply covered with drift, alluvium, and later formations. At the same time the incentive exists to create acceptable substitutes for many of the duties of metal. The problem of the economic exploration of possible mineral-bearing areas is hence a vital one.

In oil exploration, the absence of surface or shallow occurrences and the high cost of test drilling has led to the intensive study of geophysical techniques. Hence the development of the seismic method with its high certainty factor and its adaptability to standardized procedure.

Because near-surface deposits were still to be found, and because exploratory drilling was relatively inexpensive with a high certainty factor whereas the geophysical techniques applied had marked depth limitations and high uncertainty factors, mining exploration has relied essentially on geology and drilling. On the following pages, Tables A and B compare factors in petroleum exploration and mining exploration.

Geophysical methods that have been applied to mining exploration work include the following: (1) magnetic; (2) self-potential; (3) resistivity, ratiometer and equipotential line; (4) electromagnetic induction; (5) gravimetric; (6) geothermal; (7) radioactive; (8) geochemical; and (9) seismic.

Condensed from an article in *Geophysics*, October 1948.

method depends on physical-property contrast

Methods (1) to (6) can be lumped together as the force-field group, in that they are all dependent on the action of a natural or artificially created force field on bodies of contrasting physical properties. Depending on the procedure, the resultant potential, field component, or field gradient can be measured. Obviously then, many geophysical techniques involve a change in procedure without the determination of a fundamentally different physical property characteristic. This force-field group of methods has been the one essentially applied to mining.

The main limitations to geophysical methods applied to mining exploration arise from the following causes: (1) lack of sufficient physical property contrast on the part of the body or condition sought; (2) decrease of anomaly with distance to the causative body; (3) marked anomalies arising from surface features; (4) uncertainty of interpretation as measured by the actual "ore finding" or "ore elimination" information provided.

All geophysical methods in application fundamentally depend on the presence of bodies of contrasting physical property. From the observed changes in the measured physical quantity the attempt is made to derive a configuration of surface and subsurface bodies and to deduce the associated physical property differences. Geologic terms are then assigned to the derived bodies. This is

the procedure of interpretation, the first step of which is mathematical-physical, the second geologic.

Any geophysical method may be limited by lack of physical property contrasts between the ore or formation sought and its surroundings. Apart from any depth, size, or surface feature limitations, the direct detection of mineralization or ore will depend on the presence of a physical property contrast which is frequently lacking. Thus, increased porosity or fracturing may eliminate a density difference as for certain of the Labrador hematite bodies and the Missouri and Morocco mantos leads. The absence of pyrrhotite may wipe out the expected magnetic anomaly over primary or massive replacement sulphides as for certain of the sulphide lenses in the Jerome area. A high water table may inhibit the spontaneous polarization of a scattered sulphide in fractured gold-bearing quartz; e.g., MacLeod Cockshutt Gold Mines, Little Long Lac area. The fact that conducting lead-zinc sulphides are not interconnected but segregated in a non-conducting silica and siderite matrix may remove all possible conductivity contrast for resistivity and lower frequency electromagnetic methods; e.g., Coeur d'Alene. A good example is Bonne Terre, Mo., where three to five per cent lead ore occurs in the flat-lying dolomitic-limestone horizon. The increased density due to the lead is largely wiped out by increased porosity. Magnetic anomalies, in part correlatable to basement highs which may have some association with ore deposition, are largely caused by variations in the magnetic properties of the basement. Seismic-refraction work to define basement highs consistently picked out the high-velocity Bonne Terre crystalline limestone. Due to the scattered nature of the sulphides, direct detection by resistivity or low-frequency electromagnetic procedures is unlikely.

Seldom can an ore body be unequivocally detected and interpreted as such from mining geophysical work. The best chances are with large bodies such as replacement sulphides and hematite. Most finds[1] have been made by drilling what were possible anomalies (Quemont,[2] East Sullivan) or by drilling a structure or formation whose relationship to a geophysically traced horizon was well established geologically; e.g., Witwatersrand extension,[3] Steep Rock Lake.[4]

Most mining geophysical work is hence indirect and based on the tracing of formations or conditions whose relationship to possible ore locations can be deduced geologically.

force-field methods' depth limited

All the force-field methods have distance or depth limits, the actual anomaly varying with the dimensions of the body concerned. Thus the scale factor becomes important since it is really the distance or depth in terms of the dimensions of the body that is involved. Thus the 25-ft wide steeply-dipping replaced breccia under 75 ft of drift, which is the Falconbridge ore zone, would give the same magnitude of magnetic or electromagnetic field anomaly as a 100-ft wide zone of similar properties under 300 ft of cover. For narrower formations then, the decrease of anomaly with depth is rapid while for broader formations gradual. Thus it may be possible to detect broader units under considerable cover or from considerable altitude. The dimensions of most larger metal deposits, apart from porphyry coppers, are such that detection under 500 ft of cover by gravity, magnetic, electric, or other force-field means marks about the extreme limit. Thus, for gravity work a 0.05 milligal over-all probable error represents 3 to 10 million tons of 10 to 11 cu ft per ton sulphide ore under 500 ft of cover. The 3000-gamma anomalies over the Quemont copper and the EL Lynn Lake nickel bodies reduce to the order of 100 gamma at 500 ft elevation.

By comparison, it is seen that the small scale of many vein deposits, notably gold, and of the associated forma-

Table A . . . COMPARATIVE FACTORS IN PETROLEUM AND MINING EXPLORATION

Petroleum Exploration	Mining Exploration
(1) Targets are large, usually miles in dimension.	(1) Targets are small, tens to hundreds of feet in dimension.
(2) Host rock and formations are consistent over wide areas.	(2) A wide variety of host rocks and formations may occur over limited distances.
(3) Possible structures controlling occurrence are limited in number (e.g. flexure, fault, unconformity, pinched-out beds, reef) and generally tend to recur over a wide area, with odds only 10 to 1 against pay at structurally defined locations.	(3) Many possible structural and ore-depositional controls exist with odds of 100 to 1 or more against pay at any geophysically or geologically defined location.
(4) Test exploratory drilling is expensive on a per foot basis ($8.50 per ft for 5200- to 5500-ft wells in the Leduc area). A portion of these costs can be considered in the development category.	(4) Test exploratory drilling is relatively inexpensive on a per foot basis ($2 to $8), but is usually not carried beyond an economic limit of 1000 ft.
(5) The development work per test well to obtain crude is relatively inexpensive. $50,000 covers casing, cementing, and capping per well in the Leduc area.	(5) Development work to prove and obtain commercial ore is relatively costly involving considerable surface drilling, underground work, and milling. Costs may range from $1,000,000 for a small Canadian gold mine to $50,000,000, e.g. San Manuel porphyry copper.
(6) Out of a roughly $5,000,000,000 annual crude-product value, United States oil companies spend approximately $100,000,000, or two per cent, on geophysical exploration.	(6) Out of a $300,000,000 annual metal value, Canadian companies spend $5,000,000, or 1½ per cent, on exploration, largely on shallow drilling, and the rest on prospecting, geology, and ($500,000) geophysics.

Air-borne magnetometer prospecting is valuable in covering large areas and picking up anomalies. Care is needed in interpretation as anomalies may be due to many causes and overlapping of physical properties of complex areas leaves ambiguity.

tional and structural features, introduces a shallow depth limitation and militates seriously against detection even when physical property differences are present.

This so-called depth or resolving power limitation constitutes a fundamental limitation which can be pushed back only percentagewise. It seriously limits work on narrow formations or zones.

Since the surface materials, rock, clay, sand, and water, have contrasting physical properties and are nearest the recording point, surface features in mining geophysics frequently create large anomalies. These are difficult to evaluate accurately. Unknown bedrock topography beneath the surface drift in the Lynn Lake nickel area gives rise to gravity anomalies of the order of 1/10 milligals—about the same size as the expected anomaly for a few million tons of sulphide. Elevational and outcrop features in the Flin Flon area create self-potential anomalies from a few tens to hundreds of millivolts. Good-conducting wet-surface areas, as in northern Ontario and Quebec, may cause apparent resistivity changes of 95 per cent. Elevational factors must be considered carefully in any electromagnetic procedure. Magnetic surface Tertiary volcanics render magnetic work impractical in the Jerome, Bingham, and Tintic areas. Often in Canada and the United States, anomalies considered due to bedrock conditions, and drilled, were found to be actually the result of surface features and could have been shown as such.

Interpretation key factor

The major limitation to mining geophysical methods, however, is the uncertainty factor connected with interpretation. In the process of interpretation, the first step is to reproduce the observed physical data by deriving by mathematical-physical means a series of surface and subsurface bodies with associated physical properties. Theoretically, a unique solution is not possible. Actually, several configurations may reproduce the results within the range of error arising from experimental and surface conditions, and inadequate mathematical approximations. The configuration selected as most consistent with the results in view of the geologic controls will be at best a generalization of a geologic complexity. This step can be adequately carried out, although too little attention has been given to a mathematical-physical analysis of results.

The second step involves assigning geologic significance to the derived configuration. It is here that the greatest difficulties arise, for the rocks generally associated with a likely ore occurrence usually exhibit great variety and irregularity of extent and distribution, with frequently overlapping physical properties, so that a deduction of the possible idealized shapes and physical properties of the bodies causing an anomaly still leaves ambiguity as to what rocks or conditions the deduced bodies represent. Also the possibility that a given anomalous condition represents a possible ore association may be slight and yet definitely exist, thus immediately introducing a high uncertainty factor. For example, any increased resistivity anomaly obtained while working on a lake surface could be due to a steeply dipping more resistant formation. Under certain conditions the difference would be difficult to establish.

Magnetic anomalies in the Noranda area can arise

Table B . . . A COMPARISON OF PETROLEUM AND MINING GEOPHYSICS

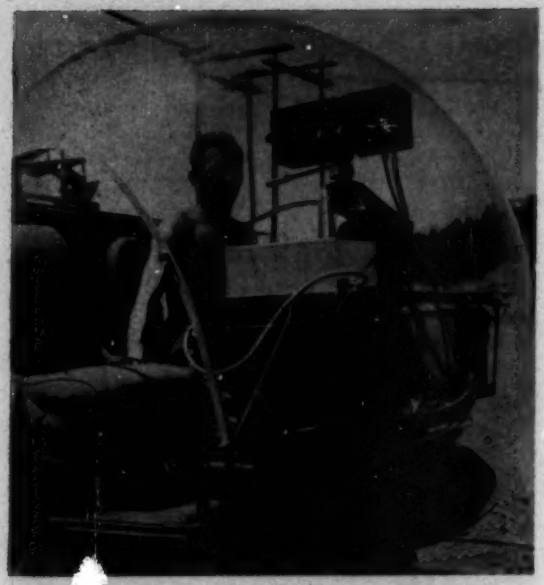
Petroleum Geophysics	Mining Geophysics
(1) In petroleum geophysical exploration, none of the procedures are direct; i.e. petroleum is never directly located, nor is this theoretically possible, except by soil and gas analysis, which in other respects is seriously limited. Thus geophysical work is directed toward providing geologic and structural evidence for deduction.	(1) Likewise in mining it is seldom possible to directly detect ore unequivocally, although it is not infrequently possible by association; e.g. the association of magnetite and pyrrhotite with nickel in Venezuela and Sudbury, respectively. Similarly, to date, most mining geophysical work has been directed toward providing geologic and structural information so that from geologic association, possible ore locations can be deduced; e.g. the tracing of the Rand extension by the magnetic slates, one of the conformable formations.
(2) Seismic methods, generally, have no serious depth limitation since the error in time measurement is independent of depth to the reflecting or refracting horizon.	(2) Force-field methods, generally, have serious depth limitations, the expected anomaly varying as some inverse power of the distance to the body. Depending on scale, this usually limits measurable anomalies to, at most, a few hundred feet from the causative body.
(3) Surface features of the unglaciated, flat-lying areas permit accurate evaluation, but occasionally give trouble; e.g. seismic ghost structures due to bedrock topographic elevations and depressions in Southern Alberta, and the difficulties arising from irregular drift for seismic and gravity work in Michigan and Pennsylvania.	(3) General surface and bedrock topographic features with the physical property and elevational differences involved frequently give rise to large anomalies difficult to evaluate accurately; e.g. bedrock topography in gravity work; surface swamps, and outcrops in self-potential, resistivity, and electromagnetic work; overlying Tertiary volcanics in magnetic work.
(4) The limited number of structural types of occurrence, the close correlation between structure and occurrence, the lateral homogeneity of the formations, and the large areal extent of the target permit relatively certain interpretation of seismic data and good geologic control.	(4) The great rock variety usually present at a metal ore deposit, the irregularity of formational extent and contacts, and the overlapping and not infrequently inconsistent physical property ranges for each rock material make mathematical-physical interpretation and the determination of the seat of the anomalies uncertain. The uncertain correlation of geology and structure to ore and the geologic possibilities admittedly present decrease the certainty of interpretation as a directive to possible ore.
(5) Where seismic procedures are applicable, the absence of structure is also recorded with a high degree of certainty.	(5) Absence of anomalies attributable to bedrock conditions does not necessarily eliminate the possibility of ore or an acceptable structural condition.
(6) Seismic procedures are applicable to 50 per cent of the possible oil areas.	(6) In large areas of geologic possibility geophysical procedures have not been economically applicable.
(7) Well-surveying methods utilizing self-potential, resistivity, radioactive, and thermal measurements record conditions largely confined to the immediate vicinity of the well.	(7) Most mining geophysical procedures are readily applicable underground in drifts and drill holes. Most of the trials have attempted to reach as great a distance as possible from the hole or drift.
(8) Because of (4) it has been possible to use standardized procedures admitting rapid areal coverage.	(8) Mining geophysical work will likely be on an "art-craft" basis with procedures, scale relations, and detail selected appropriate for the problem.
(9) Air photographs are useful in geological mapping and in planning work. Air-borne magnetic methods will yield essentially basement anomalies.	(9) Air-borne work, magnetic and other methods, and geology and alteration from air photographs should have more application to mining exploration than to oil since they provide geologic information more closely related to the rocks and conditions associated with possible ore locations.

from gabbro, scattered magnetite in andesites, and pyrrhotites either scattered or associated with dense sulphides. Conceivably the deduced bodies might all have the same approximate attitude, dimensions, and susceptibility. Actual anomalies due to the above causes occurred at Quemont, although there was some evidence for differentiation.

At Lynn Lake, gravity anomalies of 1/10 of a milligal resulted from sulphides, bedrock topography, and fingers of induration adjacent to the gabbro. Analytical means of differentiation by solving for density were applied but uncertainty still remained.

Extensive air-borne magnetic work in Canada, done independently by International Nickel and Dominion Gulf, has resulted in a whole series of magnetic anomalies that may be due to a number of causes; e.g., scattered magnetite in tuffs and flows, basic intrusive plugs, scattered pyrrhotites, and perhaps a nickeliferous sulphide body. From the air at 500-ft elevation it will be impossible to establish the dimensions and susceptibilities of bodies under approximately 1000-ft size. Even with good geologic control considerable uncertainty of interpretation will exist for any of the approximately 1000-ft-sized anomalies. And yet, a 1000 ft circle covers, and to spare, the suboutcrops of Noranda, Quemont, Hudson Bay Mining and Smelting, and the EL ore body at Lynn Lake.

In addition to the uncertainty factor of the geophysical interpretation, there is also the associated geologic uncertainty factor measured by the probability that a geo-



Jay Demming, Bell Aircraft pilot, awaits Hans Lundberg before taking off to survey the area around Amos, Quebec, with the electromagnetic equipment in the nose of this helicopter.

logically recommended set of conditions leads to discovery. The combined over-all uncertainty factor of geophysical results to geologic data to geologic deductions to localization of ore is high, several hundred to one against, and economically, it has done much to restrict mining-geophysical field work and research. Similarly, the uncertainty factor in geophysically eliminating ore possibilities may be high.

To my mind this uncertainty factor is the most serious limitation to mining geophysics and mining exploration in general. It is a challenge to both geophysicists and geologists, to the former for more scientifically based, reliable interpretative techniques and to the latter for evolving means for a narrower more reliable localization of likely ore conditions.

In short then, the essential limitations in geophysical mining exploration are the indirectness of the methods in most cases, the factors of scale and associated depth limitation, the effects of surface features, and the over-all uncertainty of interpretation in terms of the localization or the elimination of, possible ore occurrence. Each mining geophysical survey is usually a specialized problem in itself and is likely to remain so. Geophysical exploration in the petroleum and mining fields is almost comparable to highly developed and skilled mass production on the one hand, and handcraft on the other.

limitations can be reduced

Any developments suggested in mining geophysics should be such as to reduce the aforementioned limitations.

(1) In over-all application what geophysical methods cannot do is quite as important as what they can do. Little progress will be made until the limitations and shortcomings are bluntly stated. Too many mining geophysicists have been unwilling to admit the limitations. Too few engineers and geologists realize them. A realization of the shortcomings is the first step toward a healthy development.

(2) A better engineering and scientific approach is demanded. For example, if the approximate geologic conditions are known, and if the rock properties can be measured in a laboratory, or otherwise determined, it should be possible to compute the anomalies likely to result by any geophysical method. This should permit a scientifically based decision as to what method or methods, if any, warrant application. The "try everything" philosophy is extravagant, poor engineering, and an admission of inadequacy.

(3) Improved and greater use of mathematical-physical procedures should be made for the analysis of results, the quantitative evaluation of surface features, etc. Much is yet to be done in the way of direct-curve analysis, the establishment of type curves, and the use of computation charts. Comprehensive model tests should be used to check theory and to evaluate certain factors empirically, such as the electrification of tabular bodies, which cannot be handled mathematically. It should be realized that any sound interpretation has to satisfy all the physical field results as well as the geologic controls.

(4) Development of techniques permitting geophysical measurements in underground workings and diamond-drill holes is an important item. This would, in part, beat the depth limitation and greatly aid development work. Actually, magnetic, self-potential, resistivity, electromagnetic, and seismic methods, with little modification, can be applied from EX diamond-drill holes of 1¾-in. diameter.

(5) Air-borne magnetic and other air-borne methods in process of development as well as the extended uses of air photographs provide the data for rapidly obtaining a regional geologic picture and singling out areas of interest.

(6) Despite the fact that most ore deposits represent the concentration of an "anomalous" material, implying perhaps some characteristic physical property, no generally diagnostic recordable physical property or properties have been found. Any approach to a fundamentally new method should start from here, basing itself on an investigation of the physical property characteristics in the widest sense. Thus, for example, though scattered sulphides represent deposits in "mantos" and "porphyry" form, and are associated with perhaps 90 per cent of all mineral deposits, no method exists for detecting them with reasonable certainty. There is room then for fundamentally new methods.

(7) Fundamental geophysical and geologic research should be conducted to the end of establishing means for the narrower and more certain localization of possible ore areas. This should involve geophysically-basic physical property determinations on rocks from mining areas; regional magnetic, gravity, and radioactive studies; and mathematical formulation and model studies.

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[2] T. Koulomzine and L. Brossard, *Geophysics*, Vol. 12, p. 651, 1947.
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Getting Your Money's Worth

By E. H. ROSE • TENNESSEE COAL, IRON, AND RAILROAD CO., MEMBER, AIME

From the more distant members and some not so distant, the plaint is often heard that they cannot justify the expense and time required to attend the AIME Annual Meeting. Almost invariably, the reason given takes this form: "I just don't see that I would get enough out of it." Often the would-be clincher is added: "Besides, the meat of it all comes out in print anyway."

Not long ago, a group of us who have seldom missed a meeting in recent years fell to discussing this phenomenon, and found ourselves in emphatic agreement that anyone holding such a belief indicates by his first remark that he does not know how to attend a convention, and by his second, proves it. He is, by and large, the man who has never been there, and of him, there are many. Since he must often justify an expense account, these remarks are addressed to his employer as well, with the

behest that prospecting for new technological knowledge or advances is like prospecting for ore or oil: the reconnaissance crews have to get out and look methodically, and in the right places, which are not necessarily the "obvious" places.

This observer does not profess to be an expert in the matter, nor even a good journeyman instructor, but some compelling points may be ticked off by anyone who has had repeated exposure to the atmosphere of mining meetings.

(1) *Information picked up in person-to-person contacts bulks far larger in take-home payoff than the official fare.* The formal presentations necessarily are contributions to knowledge in the broad sense. They deal with the contributor's experience, not the listener's. They are a one-way conversation, so to speak. The listener takes no really active part, other than discussion from the floor and that only after the speaker has had his uninterrupted say. There is no give and take concurrent with the presentation, and afterward it is too late for the knocking about of points of detail, even if time permitted, which it never does, and even if the listeners did not self-consciously "freeze" as they attempt their remarks from the floor, which many of them do.

But in the corridors, it's different. There and in the uninhibited informality of private rooms, where kindred spirits foregather, you find the source of the kind of information you came to get—the details too small or specialized to come out in the necessarily condensed formal sessions, the latest on-the-scene accounts of experiments known to be in progress but not yet advanced enough for formal reporting, the stories of experiments that failed and hence were not published to warn others away from the same blind alley, and the innumerable straws in the wind to indicate the direction of technological progress to come. There you do not take larger topics, one at a time, and exhaust them before passing on to the next. There you really get down to cases. I tell you how I am trying to do something; you come right back and tell me how you learned to do it better and you make me a sketch. You have heard that the Doakes mill has recently done itself some good by a change of flowsheet; I have recently visited that mill and tell you about it, since it is not confidential, and a Doakes man would tell you himself if he happened to be about. I have heard that the Hoozit Manufacturing Company has recently come out with a new automatic control device; you tell me you have had one in your plant for several months and it's a honey. You have heard that my outfit is doing some work with this new method of roof pinning; that happens to be off my beat but I take you around and introduce you to a man who knows all about it, whereupon the cycle begins all over again.

Little stuff perhaps, but of good assay, and sometimes a real nugget turns up. If our friend in the first paragraph insists upon measuring dollars to the disregard of satisfactions, he might calculate that one little such item reduced to practice back home for a saving of a picayune twenty dollars a month would pay for his annual trip to the meeting, even if he came from the other side of the continent. The "regulars" know that Lloyd's would make a neat profit by writing insurance to that general effect. It is, indeed, the reason those fellows show up year after year—without insurance other than their own convictions built up out of experience.

Nor is it all little stuff. I can cite chapter and verse on two major changes of practice in large plants that came about five years sooner than they otherwise would have, as the result of just such conversations in the byways of Annual Meetings—and no confidence violated in the process. Indeed, it was discovered afterward that the basic data and interpretation pointing the way to one of them had been published as an AIME paper years before, without the potential beneficiaries reading themselves into the act.

(2) *Repeated attendance pays increasing dividends.* Implicit in the foregoing is acquaintance with those persons of the most relevant interests, and the degree of mutual benefit is measurable by the degree of mutual friendship, understanding, and respect. The standoffishness of strangers is fatal; the camaraderie of old friends, perhaps not seen since the preceding meeting, is the instantaneous catalyst that induces the real reaction of minds, and the real yield of profitable guidance on both sides. It is no accident that the mining profession is unique in being commonly referred to as the "mining fraternity" and every meeting attests the aptness of that designation. He would be a backward soul, indeed, who, after the first year or two, could come away from any Annual Meeting without at least a dozen new first-name friends, to push his circle of provincialism correspondingly outward. (It is superfluous to ask if our Doubting Thomas averages a dozen new friends a year in his field by any other means open to him, unless it be by endless travel.) Attending regularly, his contacts, instead of becoming so broad he cannot cope with them, become the more selective and fruitful. An enlightening illustration came out of the 1947 Denver Regional Meeting, when Jack Myers and I exchanged our company reports on that gathering. As Jack put it, "You wouldn't think we had been at the same meeting," for the problems and points we discussed with others were not the same problems and points, because the operations of our respective personal concern and our sources were not the same, and likewise the gleanings we deemed most worthy of reporting to our respective managements.

(3) *Reciprocity is essential.* In addition to attendance, participation in Institute activities is the key that opens the door to the benefits sought. On that point, I can speak with authority, having been an Institute member for twelve years before attending my first meeting and sixteen before serving on a committee, but thereafter diving in enthusiastically. I can correspondingly understand the mental colic of the mail-order-minded member who sends in his annual dues and expects merchandise of said value to return to him at stated intervals. The poor fellow has his frustrations coming to him, but little sympathy. He's the chap who bought a bicycle but never learned to ride it, then complains that it doesn't take him anywhere. He has never really appraised the three points made herein, or if he has appraised them, has done so

under the handicap of not recognizing the Golden Rule, in professional society affairs, as not a rule at all but an automatic proportionality, truly though tritely expressed as, "You get out what you put in." The principle is that of trade; it is as simple as that.

Many inactive members sincerely believe that they are not qualified to write papers, for lack of either material or talent. Often, that may, indeed, be true, but it does not follow that they are unqualified to pursue other activities, such as serving on national or Local Section committees, all of which is as voluntary as the writing of papers and even more rewarding. Someone may say that he has never been "put" on a committee. The process is not quite so passive; one has first to open his eyes to the many ways in which he could be useful to others and thus in due process to himself and to his employer. To be selected, he must become visible. A few thoughtful letters written to the chairmen of committees covering his field of work or his geographic area—making suggestions, offering criticisms, or even merely asking the questions he asks himself verbally—and he will soon find himself out on the main line moving with traffic. He can be perfectly selfish about it, not for a moment pretending that such activity on his part is out of the kindness of his heart or for love of his fellow man, but strictly on the basis that such is directly or indirectly a sound currency of trade for any of the several desirable objectives: professional recognition, technological information, a promotion, or a different job. It just happens to work that way, as many can attest. Even on a committee, there will be no one standing at his elbow telling him what to do. It is his in-time-well-rewarded job to think of something to do, just as in the conversations stressed under point (1) he must contribute information as well as seek it.

And so, the question "how to attend an AIME meeting" or even "how to be an AIME member" boils down to one simple principle: "Give and ye shall receive." The mechanics of doing so presume a smattering of originality and extraversion, but beyond that one could more simply convey the idea by defining how *not* to attend an AIME meeting: don't just sit still and wait for the manna to rain down. You will be disappointed if you do.

Engineering Societies Library Reports

Library costs have risen more than Library income but not as much as the cost of living. The net result of this is that the Library can purchase relatively fewer books and magazines, and the staff has relatively lower income. By placing greater emphasis on paid services and by increasing the rates for services, the percentage of income from services has been doubled since 1939.

Pending funds from the Engineering Foundation, a survey to reorient the ESL with other technological libraries in the country is to be made. It is also planned to try to obtain support from industry.

Use of the Library has leveled off this year after a spurt in the two preceding years that had raised Library use more than 20 per cent. The statistics of Library use are:

	1946-47	1947-48
Visitors served	23,557	22,228
Nonvisitors served	17,098	17,442
Total	40,655	39,670
Photostat orders	4,392	4,135
Photostat prints	53,597	49,954
Microfilm orders	114	141
Searches	140	141
Translations	45	49
Words translated	136,192	212,288
Borrowers	1,835	2,200
Books loaned	2,628	3,011
Telephone inquiries	7,358	7,263
Letters written (exclusive of book orders)	3,214	3,513

A series of bibliographies has been initiated. These are intended for general distribution and they will be sold at prices that will at least cover their cost. The first is entitled "Filing Systems for Engineering Offices." Others in the series will cover various engineering topics of current and general interest in all fields of engineering.

Some persons who come to the Library have little or no knowledge of English but current members of the ESL staff can converse fluently with these persons in French, German, or Russian and with some difficulty in six other languages. Among the translators that are subject to call are persons who can translate almost any foreign language into English.

As in the past, the Library has received many valuable gifts of books and magazines. There were no outstanding gifts during the year, but some of the larger and more useful ones were those from the following: D. W. Barron, A. Eckwall, S. W. Farnsworth, M. Pirnie, B. W. Shaffer, and F. T. Sisco. Various technical societies, publishers, and other organizations have given generously of their own publications and other publications that have come to them. The Library has been enriched by the many gifts received. Sincere thanks are extended to all donors. It now contains 166,470 volumes, 10,514 maps, and 5056 searches, a total of 182,040 items. —*Ralph H. Phelps, Director.*

Pittsburgh Off-the-Record Meeting

Under the direction of R. F. Miller, of Carnegie-Illinois Steel Corp., and G. R. Fitterer, University of Pittsburgh, a most interesting program was arranged for the Nov. 12 all-day meeting of the Pittsburgh Section. It was attended by approximately 680 persons, of which 135 were students representing the University of Pittsburgh, Carnegie Institute of Technology, University of West Virginia, and Pennsylvania State College. Since the program was off the record, no attempt was made to make notes of the remarks of the individual discussers, but each session was interesting and educational, with good discussion of the papers. The National Open Hearth Committee held the largest number of sessions but the Coal Division, Institute of Metals, and Petroleum Division also held important meetings.

The meeting was concluded with a cocktail party through the courtesy of the suppliers' group of the Pittsburgh area under the chairmanship of R. S. Runyon and a dinner at which J. E. Thornton, special agent in charge of the Pittsburgh Office of the FBI, gave an interesting talk on his personal experiences as an FBI agent.—*Hugo E. Johnson.*

LEWIS EMANUEL YOUNG

President, AIME, 1949

Omaha Public Library
Reference Dept.

Lewis E. Young, who will formally assume his duties as President of the AIME at the Annual Meeting in San Francisco in February 1949, was born in Topeka, Kansas, Oct. 1, 1878. Dr. Young received his engineering education at the Pennsylvania State College, where he received the degree of B.S. in Mining Engineering in 1900. In 1904 he received his E.M. degree from Iowa State College, and in 1915 a Ph.D. from the University of Illinois. In 1947, the University of Missouri conferred on Dr. Young *honoris causa* the degree of Doctor of Engineering.

His active career began in the educational field as instructor at Iowa State College, and following that, as professor of mining at the Colorado School of Mines, 1903-1907. While he was at Golden he launched his career as consulting mining engineer for various Western companies.

Leaving the Colorado School of Mines, Dr. Young returned to Missouri, serving the University of Missouri as director of the School of Mines and Metallurgy at Rolla, 1907-1914. Leaving Missouri he went to the University of Illinois as assistant professor of business organization, 1915-1918, during which period he wrote exhaustive treatises on mine subsidence and mine taxation, which won for him the degree of Ph.D. before mentioned.

With World War I confronting the nation, Dr. Young plunged into production work, becoming manager of the steam heating department of the Union Electric Co., of St. Louis, 1918-1922. With the completion of the Company's steam heating expansion program, Union Electric called on Dr. Young to fill the position of general manager of the Union Colliery Co., a wholly-owned subsidiary, where, for four years, 1922-1926, he pursued a program of complete mechanization of the Colliery Company's Kathleen mine, in Jackson County, Illinois.

With that task behind him, Dr. Young was offered the vice-presidency of the Pittsburgh Coal Co., which, subsequently combined with Consolidation Coal Co. and a number of lesser properties, became the Pittsburgh Consolidation Coal Co., the largest producer of bituminous coal in the world.

Dr. Young, never static, after resigning from the Pittsburgh Coal Co. in 1939, decided to go on his own, opening an office in the Oliver Building, Pittsburgh. Since then he has roamed, not only the United States, but in addition, Canada, the British Isles, France, Germany, and more recently South America, aiding and encouraging his many clients in the development of coal and nonferrous mineral properties, giving particular attention to mechanization, preparation, and cost reduction. Those who know Dr. Young best do not hesitate to say that his knowledge of mechanical mining methods is on a par with that of the top men in that field.

Dynamic in movement and speech, our friend will go anywhere, by air, land, or sea. Those who have followed the tall, rangy, one-time prof below the surface, in thin and steeply pitching seams, wonder how he keeps up his speed. No one would ever guess his age as seventy. Nowhere is he so happy as when addressing a body of young engineers, who invariably leave him with an added conception of the opportunities and responsibilities of the mining engineer. All over the United States, the one-time boys who sat in front of him in Penn State, Iowa State, Golden, Urbana, and Rolla, who are now mature men, invariably greet him effusively and affectionately, the conversation harking back to that most interesting of periods, their school days.

Through his busy career, Dr. Young has found time for writing numerous technical papers for this and other technical societies and engineering periodicals. Like practically all of the men who have achieved especial prominence in the mineral industry field, Dr. Young joined his professional society early—in 1901, the year after he graduated from Penn State. Elected a Director in 1937, he served three terms on the Board and was Vice-President from 1942 to 1945.

Dr. Young has one son, Edwin W. Young, engaged in newspaper work in the Middle West. Dr. and Mrs. Young make their home in Pittsburgh.—*E. M.*

XUM

Water, an industrial mineral, doesn't go to market in freight cars but moves in giant conduits. Here is a steel-reinforced concrete inverted siphon, 16 ft in diameter.

Water—

Industrialization is raising the standard of living of people everywhere. The common man is demanding and getting more of everything. Perhaps more markedly than most other things, he is consuming more water. A hundred years ago water for domestic use, in all but a few large centers, was lugged from wells in buckets. This still is true in many rural areas, even in the enlightened United States of America, but pumps and pressure systems are rapidly replacing the "old oaken bucket," even on farms and in isolated country homes. Nevertheless, many still fail to see water as a "commodity," in the same sense that coal, lumber, fertilizer, and bread are considered as commodities. Water is too frequently taken for granted.

If a mining man needs more air for a shaft or adit, he simply installs another blower and takes it from the conveniently adjacent atmosphere. The industrialist, needing more air for a factory or building, does the same thing. The availability of an inexhaustible supply of air for such uses is fortunate. It also would be fortunate if other elements essential to human activities were equally available, but, of course, they are not. Food, clothing,

A paper presented before the Industrial Minerals Division, AIME, at the Oct. 24 meeting in Los Angeles.

Transporting water by canal is one way to get it there. There are 63 miles of concrete-lined open canals in the 242-mile main aqueduct system which carries water from Lake Havasu to three million inhabitants of Southern California.

Lowest Cost Industrial Mineral

By JULIAN HINDS • GENERAL MANAGER, METROPOLITAN WATER DISTRICT, LOS ANGELES

shelter, and the thousand and one things required to meet modern needs are obtainable only at the expense of exertion.

There was a time when water for most people and for most purposes was almost as abundant as air. Our not too distant ancestors, thinly scattered over humid areas or grouped in small numbers about oases, gave little thought to water as a problem—except in times of unusual drought. If more water was needed, another bucket was sent to the spring or stream, or another shallow well was dug. Increasing numbers and the spreading of populations into arid regions have changed this. Water has become one of the elements that must be striven for.

This change has come about so gradually that the average man on the street is not too painfully aware of it. The city dweller thinks of water as something that comes out of faucets. If he wants more water, he buys another faucet, little aware of the effort often required to find the water, refine it, and pipe it to his outlet. Ordinarily, this is as it should be. Production is left to experts, just as the production of coal or copper is left to the expert miner and metallurgist.

At times, however, the consumer needs to give serious thought to the nature and adequacy of the source of his

Lake Havasu reservoir is a stock pile of water for the Southern California area market. The building in the picture is the intake pumping station which starts the water on its way over the longest man-made aqueduct system in the world.

Hoover Dam, keystone of the Colorado River aqueduct development program, measures 727 ft from foundation to crest.

water. This applies to the home owner as well as the miner about to open a milling plant in an arid region. It applies particularly to those proposing to initiate water-consuming industrial enterprises.

Unfortunately, water is all too frequently the last thing a promoter thinks of. This was particularly true during the war. Factories and housing projects were built with great abandon on flat spots that could be bought cheaply, only to discover too late that the site was cheap because it had no water.

The same thing can happen in peacetime. As a recent example, the promoter of a postwar cement project in southern California acquired suitable deposits in the desert, arranged for a power supply, expended great effort locating the required machinery, and was about ready to start construction before investigating the water supply. There was none. Mining ventures likewise have been developed and abandoned because of inadequacy of water supply—a condition which should have been foreseen. The same careful advance consideration should be given to water as is given to power, raw materials, and other essentials.

The water system built along the Colorado River aqueduct of the Metropolitan Water District, to supply water for construction purposes, affords a good example of water planning for a specific enterprise. This great waterway was to be built 250 miles across a desert, devoid for much of this distance of any visible water for the maintenance of life or for construction purposes. Careful reconnaissance indicated the possible presence of underground bodies of water in rather widely separated desert basins; many were salty, but usable supplies were found at forty- to fifty-mile intervals. Obviously, it would have been uneconomical to require each individual contractor to transport water over such distances. Consequently, as a preconstruction enterprise, the District developed all of these sources, provided pumps and storage reservoirs, and laid a construction water line for the full length of the project. Fifteen usable wells, varying from 16 to 785 ft in depth, were drilled in half a dozen locations. There were also a number of salt wells and "dusters." The supply line consisted of 180 miles of 5-, 6-, and 8-in. diameter lightweight, continuously-welded steel pipe, laid in shallow trenches. The total cost of the system was $847,000 and it was much more than worth it. The supply was adequate.

Such elaborate planning of a water supply for an individual project is, of course, unusual. Most large enterprises can tap some community water system. Before risking any great investment, however, both source of supply and adequacy of delivery system should be investigated.

Most water-supply systems have grown more or less piecemeal, starting with a few families and expanding by various expedients with the growing population, systematic planning being introduced at some later date to avoid an impending disaster. In this way, the great modern water developments of the world have grown.

A most interesting example is found in the development of water in southern California. The white man found this an arid region, an excellent place for a few people to live, but subject to severe and prolonged droughts. During wet periods there were lush pastures, springs, and flowing streams, encouraging increased development, expansion of herds, and the introduction of irrigation. Then came drought. Irrigation ditches ran dry, cattle died, and people moved away. But in spite of these periods of discouragement, there was some permanent development. The climate was good, soil fertile, and all kinds of fruits and crops flourished wherever and whenever there was water.

Ground water as a source of irrigation supply was not at first taken seriously, but wells were, of course, resorted to for domestic supplies, and at times of drought for

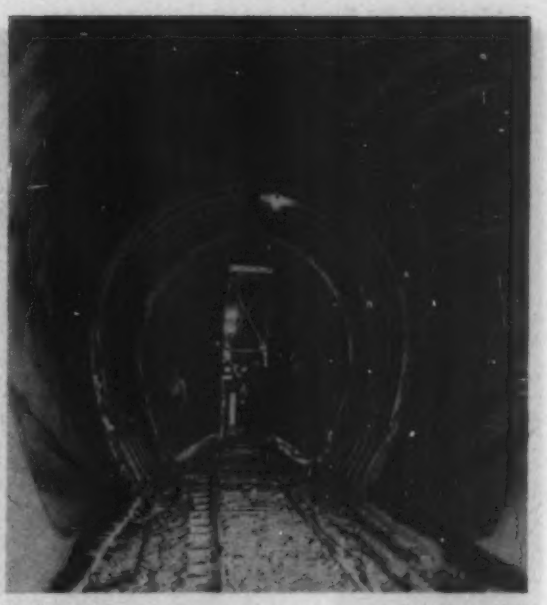
watering livestock and perhaps for home gardens. The early dug wells merely tapped shallow surface sources, but finally, with the introduction of the drilled well, someone pierced the clay cap and struck a gusher—a bountiful artesian flow. The boom was on! Here were vast expanses of wonderfully fertile lands, with a bountiful water supply just a few hundred dollars beneath the surface. Development went forward at a stupendous rate. Nobody asked where the water came from, how much there was, or how long it would last. There was no organization to ask such questions and the individual farmer was too busy to ask anything. The supply was looked upon as inexhaustible, and wells multiplied.

Soon outflow began to exceed replenishment. Pressures dropped and wells ceased to flow. But the farmers, now grown wealthy, were loath to walk off and leave their homesteads. Furthermore, they could now afford to pay for water—they could afford to pump it. And so pumps went down as fast as artesian flows stopped. And more pumping wells were drilled, still with the feeling that there were great underground oceans of fresh water, to all intents and purposes inexhaustible. And thus began one of the most stupendous mining operations of all time.

As geologists later explained, there actually was a vast, though not inexhaustible, underground storehouse of water. Practically the entire coastal basin is deeply underlain with porous detrital fills, covered with a blanket of topsoil and clay of varying thickness. Each year a small portion of the sparse rainfall and meager mountain runoff around the upper perimeter of the basin sinks into the ground. During prehistoric ages these small percolations completely filled the underlying strata and welled up against the clay cap covering the lower portions, creating an artesian pressure. It was thus revealed that the early settler's herds had died of thirst on the roof of an enormous lake of good water.

But it was only a lake and not an inexhaustible sea of fresh water, as many wishfully believed. With increased pumping, water levels sank and many wells went dry, or lowered levels permitted sea water to flow landward, contaminating the source of supply. Ultimate exhaustion became obvious, but abandonment was by now out of the question. Experts were employed and the problem was studied from all its angles. Steps were taken looking toward complete conservation of all flood waters formerly wasting into the ocean. Spreading works were constructed to encourage percolation into the underground basin, and surface storage was created where possible.

But these measures were inadequate. An annual rainfall of 15 in., no matter how thoroughly it is conserved, cannot support a semitropical civilization. Importation of water was obviously essential. There is no long river bringing water in naturally from distant sources, and near-by surrounding territory is true desert, producing no worth-while runoff. So, early in the present century it became evident that an artificial waterway to some distant point must be constructed. As a result, the then small City of Los Angeles voted the stupendous sum of $23,000,000 to build an aqueduct to tap the Owens River, 250 miles to the north. This river collects the drainage from the precipitous eastern slopes of Mt. Whitney and other snow-capped mountain peaks of the High Sierras.



Setting steel to reinforce concrete in a 16-ft high conduit.

The aqueduct was completed in 1913 with a capacity of 450 cfs. It was expected to end the water needs of Los Angeles for all time. But just as the discovery of artesian flow engendered overdevelopment, so did the introduction of Owens River water. The inexhaustible idea was again rampant, and the city began doubling in population every ten years. Leaders soon saw that the battle for water had just begun and eyes were turned to the only other adequate source—the Colorado River—frequently referred to as "the last water hole of the Southwest."

Water from the Colorado River for the coastal areas of southern California could be obtained only from the flood flows. Normal low flows were already completely appropriated. The creation of storage on the main river was not a job for a single community. The stream is interstate (in fact, international), floods are great, and silt is a problem. The political situation was complex. But the problem was courageously attacked and solved.

The amount of work involved has been prodigious. Interstate compacts, enabling acts in Sacramento and Washington, and contracts and agreements on a national scale consumed unimaginable time and effort. Finally, construction of Hoover Dam by the U. S. Bureau of Reclamation was authorized. The Metropolitan Water District, comprising the principal cities of the South Coastal Plain, was organized, and $220,000,000 worth of bonds was voted to build an aqueduct to bring more than one million acre feet per year of the conserved water to the needy coastal communities. The job was started in the bottom of the depression and finished just before the beginning of the war, substantially under the original estimate of cost.

This aqueduct again was expected permanently to end the water worries of southern California. It is now evident that this is not the case. The necessity for some

Barring down after the blast which holed through the San Jacinto tunnel. This tunnel pierced 13.04 miles of solid rock in the San Jacinto mountain range and was the most difficult unit of the entire metropolitan aqueduct construction.

limitation of ultimate development is likely unless an additional source beyond "the last water hole" is found and tapped.

This story illustrates the effort involved in planning for a water supply. Most systems are, of course, smaller and simpler. Many of them have been planned with relatively as much care as that described, but usually with less elaborateness. Many small municipal and private systems are still going largely on faith and although usually adequate for ordinary needs, cannot stand a sudden expansion of demand. A prospective investor should carefully check the adequacy of such supplies.

Reference has been made to the extraction of ground waters in the southern California coastal area as a mining operation. Water being a mineral, this reference is perhaps justified by the dictionary definition of mining. The primary distinction between water mining and the mining of other minerals is that water is sometimes replenished by percolating rainfall, permitting the continued repetition of the mining operation. In the Los Angeles coastal area this was only partly true. In fact, the foundation of the present great civilization in this region was built on fossil waters, accumulated through countless prehistoric ages. These basins never again will be fully filled, and the "take" must now be limited to the annual crop. Nevertheless, the beneficial effect of the fossil waters was great. The artesian wells produced the wealth that could afford to pump; the pumped wells produced the wealth that could afford to build the Owens River aqueduct; and the supply from this source produced the wealth required to go to the Colorado River. If any of these links had been missing, the chain could not have been forged.

Production of water by mining operations is, of course, not limited to southern California. Well waters are used throughout the world for individual supplies, municipal supplies, and irrigation. Production is often deliberately undertaken on a pure mining basis, with no hope or expectation of replenishment. Desert lands underlain by nonreplenishing water bodies have been hurriedly put into cotton or other temporarily high-priced crops, with the hope of a quick return, and with the expectations of abandonment after a few years, but such operations are likely to be detrimental to adjacent lands depending on a perennial underground water crop.

Water, like other mineral products, must be transported to its points of use after it is "mined." Sometimes it also must be refined—that is, softened or otherwise purified. In contrast to most commodities, water is delivered right where it is wanted, as wanted. It is not necessary to go to the railway station, warehouse, or store, and haul it home; or to wheelbarrow it in from the front yard. Its delivery is complete and the price of delivery is ridiculously low.

When the Colorado River aqueduct shall have reached full development, it will be capable of transporting 1 2/3 billion tons of water per year from 300 to 400 miles, lifting it through a height of over 1600 ft, and delivering it wholesale into the water systems of the coastal area at a cost slightly over one cent per ton, including interest on investment, depreciation, power for pumping, and all operation and maintenance costs. Refining (softening and filtration) will add another half cent per ton to the wholesale price. The retail price of water for household use in southern California will average about five cents a ton, delivered into the sink or bathtub, as and when needed. Irrigation and industrial water is much cheaper.

Thus the water producer sets a standard of economy which other producers and shippers will find it hard to approach—not because the water man's problems are easier, but because conditions favor low-cost production and because the volumes handled are so enormous.

JOHN FLICKINGER MYERS

Chairman, Minerals Beneficiation Division, AIME

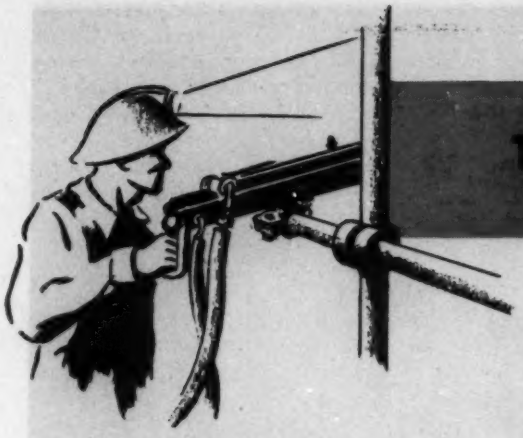
In Emporia or Claremore, time was when a path was beaten to the door of the local sage. Nowadays, the beginnings of such a path are discernible in Tennessee, as folks of the metallurgical persuasion find it to their pleasure and profit to call upon the Sage of Copperhill. They come, more and more respectfully as the years go by, yet to ever fewer persons is he known as Mr. Myers, but to more, eloquently, as Jack. Find better ways to run your mill, find happier means of co-ordinating your humanities or serving your professional society, and it's just like the man said about the mousetrap.

A druggist's son, born in Wisconsin, May 24, 1889, reared on the Bible in Ohio and Indiana, and completing his education in Colorado, this now indisputably 24-carat Tennesseean has had a checkered career. Going West as a laborer at the tail end of the 1907 panic, he did not make his fortune but he did gain an understanding of labor that in later years endeared him to his men. Graduating in 1913 from Colorado School of Mines with the degree of E. Met. and a string of football letters (also earned the hard way, at tackle) he went to work in Butte & Superior, just at the beginning of the Golden Age of flotation.

A year later, Jack is starting up the flotation plant of American Zinc at Mascot, Tenn., and putting an item into the textbooks, to wit, that copper sulphate is vital to the flotation of zinc sulphides. A year after that, now with New Jersey Zinc at Austinville and Canon City, he rounds out this discovery with first-order pioneering in alkaline circuits, and a patent or two. It was in 1926 that he joined Tennessee Copper to begin a dogged uphill fight to attain the frankly unattainable, such as a premium iron sinter from a three-metal *sulphide* ore, meaning a sinter containing less than 0.10 per cent copper or zinc. That takes some doing.

In a small operation in a little town, Jack has won international recognition. The credit he gives to others, with such compelling plausibility that maybe we shouldn't go into that. First, there's Billie, the girl he met in Butte, married in 1915, and has stayed married to ever since. Whatever their other doubts, those who know Billie concede that Jack showed early intelligence. (They have one son, Lorrin, who is now bouncing upward in NBC in a curiously reminiscent pattern.) Second, there's the AIME. Jack says—and so help me, he can prove it!—"Ninety per cent of our success here has come from AIME contacts. Sometimes I am ashamed of how little we ourselves have done and how much other folks have helped us."

We can't rightly say how much of that last is accuracy and how much is modesty, but whatever the ratio they add up to a humility the rest of us could do with a lot more of.—*E. H. R.*



THE DRIFT OF THINGS

. . . as followed by EDWARD H. ROBIE

A Fourth Round?

Talk is increasing about another round of wage increases—the fourth round. True, the cost of living has risen by some 7 per cent during the last year, so on this basis some further wage increase can be considered justified. But the rising cost of living shows some signs of tapering off; in fact, for the last month reported, it did drop off by a fraction of a point, the first time this has occurred. If this means that the advance has been stopped, then it is to be hoped that further wage increases can be held in abeyance, for experience has established the fact that a national round of wage increases causes a rise in the cost of purchased goods and services in an equal or even greater dollar amount than the increase in employment costs. However, the labor unions argue that, in the words of Gershwin's song, this "ain't necessarily so" —that the increase should come out of swollen profits.

Mr. Holman on Petroleum Trends

One product of the mineral industry that seems to be in increasing demand every year is petroleum. Even the excessive wartime demand was exceeded in the first year after hostilities ceased and the consumption has set new records every year since. Unlike many of the metals, however, petroleum has always been found in peacetime in sufficient quantity to meet all demands. As to the future, some have questioned whether we can count on the necessary increase in United States output or imports, and feel that some reliance will have to be placed on synthetic production from natural gas, oil shale, or coal.

In a talk before the Texas Mid-Continent Oil and Gas Association recently, Eugene Holman suggested that we could not count on the Middle East for a part of our oil except as a temporary measure, adducing two main reasons: first, Europe will soon be able to absorb all of the Middle Eastern production, when the necessary refineries are built; and second, for American capital, the cost and risk of development so far away are too high and the distance to market in this country too far, with import duties also to be paid.

One way that Mr. Holman thinks the problem of balanced supply and demand can be met is by improving the efficiency of oil-consuming equipment. He cites the Diesel locomotive as the outstanding example at present, for it will do the work of the oil-fired steam locomotive with about one fifth of the oil. Also, we may look for greatly increased automobile engine efficiency, and as gasoline for motor vehicles accounts for some 41 per cent of our petroleum consumption, any appreciable increase in efficiency here means much. Another economy will be found in the increasing ability of refineries to make gasoline and Diesel oil out of residual oil that was formerly burned, which can be displaced by coal, natural gas, or imported residual fuel. Presumably, therefore, fuel oil may become relatively more expensive than gasoline or Diesel fuel.

Annual Reports

Each year recently we have noted an increased tendency for mining companies, particularly those that have a product to sell to the general public, to issue fancy annual reports, printed in several colors on slick paper with plenty of photographs and art work. These are nice to look at but whether or not the companies get their money's worth out of them is questionable. Is this fancy presentation what the stockholders want?

Elmo Roper, while his reputation was still good, recently conducted an exhaustive survey for the Controllership Foundation (1 E. 42d St., New York City 17) which has published his findings in a pamphlet under the title "What People Want to Know About Your Company." It discloses that the average stockholder has little interest in corporate financial data, and uses other means of keeping track of his investment and deciding when to buy or sell. Some forty per cent of "run-of-mine" stockholders said they found no utility in the annual brochures they received. They want to know what the chances are that the company will safeguard its capital and pay the same or bigger dividends and they would appreciate a little discussion along this line. Only big investors want financial details, and they want much more than is given in the usual report.

So the Foundation recommends a brief statement, to go to all stockholders, outlining earnings, dividends, and the general financial position and outlook of the company, and offering a complete report on request. The latter would be a full-scale annual report designed primarily as a source document for those who wish ready access

to cold statistical facts. Employees would also like the brief digest.

The above applies to companies in general—not specifically to mining, metallurgical, or oil companies. For companies in the mineral industries field, we think AIME members would like to read in addition a statement every year (maybe 2000 words for the big companies, ranging down to a few hundred for the smaller companies) outlining the properties worked, new methods and equipment used, ore reserves, grades, recoveries, costs so far as can be divulged, results of exploration and development, new products and markets, labor conditions, names of operating officials, and a few other data of this general nature. But stockholders would not be so much interested as professional men, so we suggest that a brief annual report giving this information be offered for publication in the journals serving the industry.

News From the AEC

Not a great deal of news regarding its raw material supply emanates from the Atomic Energy Commission, but there seems no reason to doubt that most of the domestic supply of uranium ore continues to come from western Colorado, with that area also affording most promise for the future. Thus one of the oldest settled areas of the country, which was inhabited fifteen hundred years or more ago by the cliff dwellers, affords the newest of man's vital minerals. Within the last two or three months, arrangements have been made to facilitate the treatment of uranium ores offered by the individual prospector and operator. The U. S. Vanadium Corp. (Carbide and Carbon subsidiary) has agreed to purchase from independent miners, for treatment at its plant at Rifle, Colo., 63 miles northeast of Grand Junction, any ores adaptable to the process used there. Formerly, only company ore was treated. This will afford a market for ore mined in the northern part of the Colorado plateau and eastern Utah, and it is thought the plant may now operate at twice the scale that it has heretofore.

Another item of news has to do with southwestern Colorado, where the Vanadium Corporation of America is to take over and rehabilitate, at a cost of some $200,000, the vanadium-uranium mill owned by the Atomic Energy Commission at Durango, and formerly owned by the U. S. Vanadium Corp. Some of the ore supply for this mill, which is expected to go into operation later this year, will come from Navajo Indian lands, for which the Indians will receive a royalty. As at the Rifle plant, ore will be received from independent miners.

Vanadium Corporation also plans to erect a pilot plant in the White Canyon district of San Juan County, Utah, which heretofore has not been a producer but which has small, flat lenticular deposits of copper-uranium minerals. The mineralization extends across the line into Arizona, and prospecting should be stimulated.

These plants should do much to dissipate the dissatisfaction that many independent operators have voiced in the past concerning a satisfactory market for their product. The price they will get, however, is not a matter of bargaining between the miner and smelter, as for base-metal ores: it is set by the AEC, presumably at a level which they think will provide a reasonably adequate supply.

Many inquiries are also reported by the AEC regarding the possible value of thorium as raw material for nuclear fission. Monazite ore is the principal source of thorium, but there is little encouragement at present for producers of that mineral. Uranium 233 can be derived from thorium in a way similar to that in which plutonium is derived from uranium, and uranium 233, of course, is a desired fissionable material. However, complex research problems remain to be solved for the large-scale utilization of thorium in this way. Maybe in ten years or so monazite will be a raw material for nuclear energy, but not now. But until then, it remains the only known source of cerium and some other rare-earth metals which have varied, even though not extensive, uses.

And monzonite, if some prospector asks, is as worthless as ever.

Then and Now

When we were a little boy the first real engineering job that we had assigned to us was the operation of a small wood-fired boiler supplying steam to a pump that forced water uphill to a tank a few hundred yards away for irrigation in an orange grove. Our principal job was to keep the steam pressure up to at least 60 lb and to whistle for help when the water got near the bottom of the gage glass, for we were not quite equal to manipulating the injector or "inspirator" as it was called. Occasionally a bad and bigger boy would scare the daylights out of us by coming around, tying the safety valve down, and running the steam pressure up to about 90 lb, which we thought likely to blow the whole place, including us, to smithereens.

Our mind ran back to these early days when we read the other day of a new Westinghouse 100,000-kw turbine that runs at such a high temperature and pressure that the steam pipes feeding it glow a dull red. The steam is at 1500 lb pressure and at a temperature of 1050F. This is 50° higher than any temperature previously used in turbines. To operate in the dull-red region all high-pressure parts of the turbine were made of 18-8 stainless steel. Fabrication of parts from this hard-to-work material was difficult.

Each 50-deg. increase in the steam temperature means a saving of about 1.4 per cent in fuel. Back in 1915 steam turbines averaged only 525 kw-hr per ton of coal burned. By 1945 the figure was 1550 kw-hr as an average for all plants, old and modern, then in use. This new turbine will produce about 2500 kw-hr of electrical energy from each ton of coal burned.

We All Have Them

We suppose that readers of this journal expect its articles to be couched in good English, but sometimes when we have to rewrite articles written by foreign engineers whose knowledge of English is not too good, we run into expressions that we hate to change. For instance, one writer states in his manuscript that, in a certain foreign country, shortage of labor coupled with demand for increasing production "has made painly headache to the leader of the industry." Painly headaches are not unknown to the leaders of industry in the USA either, nor to editors and acting secretaries, it might be added.

Program, Annual Meeting, AIME, San Francisco, February 13-17, 1949

MBD, Minerals Beneficiation Division; MIED, Mineral Industry Education Division; SEG, Society of Economic Geologists; IMD, Institute of Metals Division; ISD, Iron and Steel Division; EMD, Extractive Metallurgy Division.

Sunday, February 13

2 p.m.—MBD (*Business Session*).
2:30 p.m.—MIED (*Mining and Metallurgy Forum*).
7 p.m.—MIED (*Petroleum, Geology, Geophysics Forum*).

Monday, February 14

8:30 a.m.—Registration.
9 to 9:30 a.m.—Meeting of presiding officers and authors of the day.
9:30 a.m.—Section Delegates.

9:45 a.m to 12 m.

Coal Division and MBD (*Preparation*).
Health and Safety in Mines.
Industrial Minerals Division.
MIED.
Institute of Metals Division.
Iron and Steel Division.

12:15 p.m.—All-Institute Luncheon.

2:30 p.m.

Section Delegates.
Mining Methods Committee.
MBD (*Grinding*).
Industrial Minerals Division (*Economics*).
Petroleum Division (*Production Review*).
Coal Division (*Preparation*).
Extractive Metallurgy (*Lead and Zinc*).
Institute of Metals Division.
Iron and Steel Division.

4 p.m.—Research Committee (*Annual Meeting*).
5 p.m.—Executive Committee, Coal Div.

Evening—Informal Dinner Dance.

Tuesday, February 15

8:30 to 9 a.m.—Meeting of presiding officers and authors of the day.

9 a.m. to 12 m.

Petroleum Division (*Economics*).
Coal Division (*Preparation*).
Mining Methods Committee.
Industrial Minerals Division.
MBD (*Flotation Practice*).
Mining Geology Committee and SEG.
IMD (session preceded by business meeting).
Extractive Metallurgy (*Lead and Zinc*).

9:45 a.m.—Woman's Auxiliary (*Annual Meeting*).

11 a.m.—IMD Annual Lecture.

12:15 p.m.—Luncheons

MIED. MBD. Coal Division.
Mining Geology Committee.
Metals Branch Luncheon.

2 p.m.

Executive Committee, ISD.
Annual Institute Business Meeting followed by meeting of Board.
Mineral Economics Committee.
Mining Methods Committee.
Mining Geology Committee and SEG.
MBD (*Flotation Theory*).
MBD and ISD (*Pyrolysis and Agglomeration*).
Coal Division.
Industrial Minerals Division.
Institute of Metals Division.

Evening

Petroleum Branch Dinner.
SEG Dinner.
Stag Party.

Wednesday, February 16

8:30 to 9 a.m.—Meeting of presiding officers and authors of the day.

9 a.m. to 12 m.

Petroleum Division (*Technology*).
Coal Division.
Mining Methods Committee and Industrial Minerals Division (*Phosphate Symposium*).
MBD (*Hydrometallurgy*).
Mining Geology and SEG.
Extractive Metallurgy (*Blast-furnace Charge Preparation and Dross Treatment*).
9 to 11 a.m.—Iron and Steel Division.
9 to 11 a.m.—Institute of Metals Division.

9:45 a.m.—Woman's Auxiliary (*Round Table*).

11 a.m.—Howe Memorial Lecture.

12:15 p.m.—Luncheons

Industrial Minerals Division.
Mining Methods Committee.
Executive Committee, IMD.
U. S. Section, PAIMEG.

2 p.m.

Petroleum Division (*Technology*).
Coal Division.
Mining Methods Committee.
Mining Geology and SEG (*Atomic Mineral Deposits*).
MBD (*Hydrometallurgy*).
MBD and Industrial Minerals Division.
Industrial Minerals Division.
Powder Metallurgy.
Institute of Metals Division.

Wednesday, 2 p.m. (continued)

Extractive Metallurgy (*Lead and Zinc*).

5 p.m.—Executive Committee, Industrial Minerals Division.

Evening

Annual Banquet and President's Reception.

Thursday, February 17

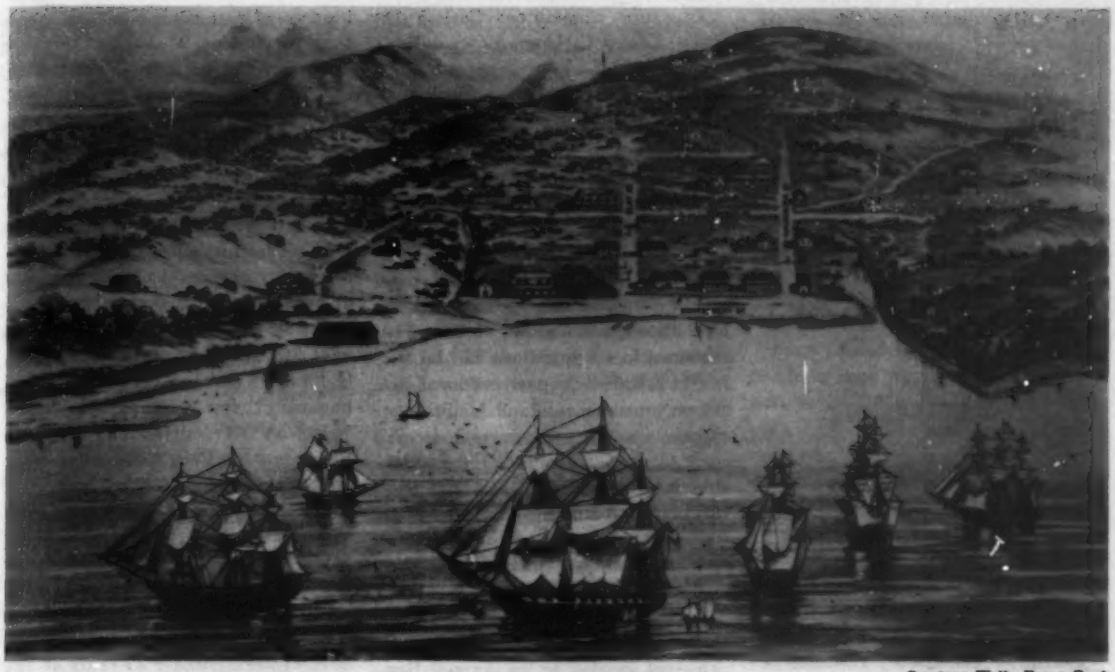
8:30 to 9 a.m.—Meeting of presiding officers and authors of the day.

9 a.m. to 12 m.

Mining Methods.
Geophysics.
MBD (*Gravity Separation*).
Extractive Metallurgy Division; Joint Session, EMD, Industrial Minerals, and Iron and Steel Divisions (*Titanium*).
Industrial Minerals Division.
Powder Metallurgy, IMD.
Executive Committee, Petroleum Division.

2 p.m.

Forum for Students.
Geophysics.
Powder Metallurgy, IMD.
MBD "Cleanup" Session.
Research Committee on Comminution.
Extractive Metallurgy (*Copper and Aluminum*).
SEG (*Geology of Ground Water*).
Executive Committee, Petroleum Division.



View of San Francisco, called Yerba Buena, before the discovery of gold in 1848. Courtesy Wells Fargo Bank

Every Field of AIME Activity to Be Covered in Over Sixty Sessions at Annual Meeting in San Francisco Feb. 13-17

THE Institute's 1949 Annual Meeting—its 168th general meeting—will be held in San Francisco, Feb. 13-17. This is only the second annual meeting in recent years to be held outside New York City, and the first ever held on the Coast. Under the chairmanship of William Wallace Mein, Jr., plans are rapidly taking shape to make it an outstanding event. It is timed to coincide with the Centennial Celebration of the California gold rush. Entertainment will be in traditional San Francisco style, with a social program of more than usual interest. Mrs. H. Robinson Plate, Chairman, Northern California Section Woman's Auxiliary, promises the ladies a time to remember.

Technical sessions, numbering more than sixty, will be held by practically all Divisions and Technical Committees of the Institute and many group dinners and luncheons are scheduled.

Airplane flights covering points of cultural, industrial, mining, and geological interest are being scheduled for Feb. 15, 16, and 17. They will be courtesy of Pan American Airways. For details of the post-meeting tour to Hawaii see page 635, Nov. M&M. There is some talk of a winter trip to the Yosemite Valley.

Headquarters will be the Fairmont Hotel. Members who have not yet made arrangements should write for hotel reservations to AIME Housing Bureau, Room 200, 61 Grove St., San Francisco 2. Give a first and second choice of hotels, and enclose a deposit of $5 per person or $10 per room. Some informal get-togethers are scheduled for Sunday, Feb. 13, and registration starts Monday morning.

A fee of $3 will be charged members at time of registration; nonmembers, $5.

The Section Delegates meet Monday morning and afternoon. The Institute annual business meeting on Tuesday afternoon, to which all members are invited, will be followed by an executive session and a general meeting of the Board of Directors.

The welcoming luncheon for members, their ladies, and guests, will be at the Fairmont Hotel, Monday. Ticket, $3.75.

Dinner Dance, Monday evening. Ticket, $7.50.

Stag Dinner, Tuesday evening. Ticket, $10.

Institute Annual Banquet, Wednesday evening. Ticket, $10.

All reservations for functions should be made by mail to Mr. Worthen Bradley, Room 200, 61 Grove St., San Francisco, and be accompanied by check in full, payable to George H. Playter, Secretary-treasurer, San Francisco Section AIME. Tickets will be mailed for all reservations received up to Feb. 1. No advance reservations can be accepted except by mail.

Dinners—The annual Branch (IMD,

ISD, EMD) dinner and the annual dinner of the Petroleum Division (Petroleum Branch) will be on Tuesday evening. Same evening, annual dinner of the Society of Economic Geologists which is meeting at joint technical sessions with the Mining Geology Committee.

Luncheons — During the Annual Meeting these special luncheons will be held:

MONDAY

All-Institute Luncheon.

TUESDAY

Mining Geology Committee.
Coal Division.
Minerals Beneficiation Division.
Mineral Industry Education Division.
Metals Branch (IMD, ISD, EMD).

WEDNESDAY

Mining Methods Committee.
Industrial Minerals Division.
Executive Committee, Institute of Metals Division.
U. S. Section, PAIMEG.

The annual meeting committees are as follows (entire personnel will be given in final program):

William Wallace Mein, J. D. Mackenzie, Donald H. McLaughlin.

General Committee: Wm. Wallace Mein, Jr., chairman; Edward Wisser, vice-chairman; George H. Playter, secretary-treasurer.

Finance Committee: Walter L. Penick, chairman; W. C. Collyer, vice-chairman; Gilfry Ward, vice-chairman.

Entertainment and Hospitality Committee: Worthen Bradley, chairman; Granville S. Borden, vice-chairman.

Advisory and Reception Committee: Robert A. Kinzie, chairman.

Banquet Committee: Walter L. Penick, chairman; Worthen Bradley, vice-chairman.

Dinner-Dance Committee: P. R. Bradley, Jr., chairman.

Stag-Smoker Committee: Herbert A. Sawin, chairman; Granville S. Borden, vice-chairman.

"All-Institute" Luncheon Committee: George H. Playter, chairman.

Hotel Committee: W. W. Bradley, chairman: E. B. DeGolia, vice-chairman.

Publicity Committee: Lewis A. Parsons, chairman.

Education Committee: Carlton D. Hulin, Lester C. Uren, Edward Wisser, Bernard York.

Field Trip Committee: Gordon I. Gould, chairman.

Authors and Presiding Officers— Get-together after-breakfast meetings of presiding officers and authors will be held at 9 to 9:30 a.m., Monday, and 8:30 to 9 a.m., Tuesday, Wednesday, and Thursday. The meetings will be casual in nature—they will afford an opportunity for authors and chairmen to ask questions and for the Institute staff to impart pertinent detail on arrangements and facilities at specific sessions. The presiding officers' envelopes, containing the available papers, written discussion, etc., will be distributed to the chairmen of sessions at these meetings, and chairmen and authors will have opportunity to become acquainted.

Robert Gordon Sproul, president, University of California, will be the principal speaker at the Annual Banquet at the Palace Hotel on Wednesday night, at which honors will be conferred as follows:

Charles F. Rand Medal to Harry Carothers Wiess (posthumously) "for energy, wisdom, and administrative ability which found expression in major contributions to the economy of the nation and the world; for high courage and vision in services to the petroleum industry; for ceaseless efforts in fostering during World War II the production of strategic supplies; for a greatness of character which showed itself in his many philanthropies and in the respect of all who knew him."

William Lawrence Saunders Medal for distinguished achievement in mining to Stanly A. Easton "for his leadership and activities over a period of fifty years in the development of the Bunker Hill and Sullivan, one of the great mining enterprises of the world."

James Douglas Medal in recognition of distinguished achievement in nonferrous metallurgy to William Wraith "for conspicuous leadership in and fundamental contribution to technologic progress in the arts of beneficiating ores of nonferrous metals, especially those of copper."

Erskine Ramsay Medal in recognition of distinguished achievement in the production, beneficiation, or utilization of bituminous or anthracite coal to Eugene McAuliffe "for his leadership and initiative in the promotion and achievement of better safety, more efficiency, and improved working conditions in coal mining, which have led to a more healthful coal industry."

Robert W. Hunt Award to M. Tenenbaum for his paper entitled "Structure, Segregration, and Solidification of Semikilled Steel Ingots."

The Institute of Metals Division Annual Award will be presented to E. A. Gulbransen and J. W. Hickman (posthumously) for their paper entitled "Electron Diffraction Study of Oxide Films on Iron, Cobalt, Nickel, Copper and Chromium."

J. E. Johnson, Jr., Award to John Daniel Saussman for his paper entitled "Sinter Practice, Kaiser Company, Inc., Fontana, California."

Rossiter W. Raymond Award for the best paper published by a member of the Institute under 33 years of age to M. Tenenbaum for his paper entitled "Structure, Segregation, and Solidification of Semikilled Steel Ingots."

Alfred Noble Prize (joint award of the Founder Engineering Societies and the Western Society of Engineers) to Robert L. Hoss for his paper entitled "Calculated Effect of Pressure Maintenance on Oil Recovery."

Also at the banquet the following, who have been members of the Institute since 1899, and several of whom will be present, will be inducted into the Legion of Honor:

Eugene Antz	Ernest A. Hersam
George H. Ashley	Henry M. Lane
H. A. Brassert	C. M. Lewis
John Cabot, Jr.	J. F. Mitchell-Roberts
Norman Carmichael	Lord Skelmersdale
Arthur Chippendale	Harold Abbot Titcomb
Carl R. Davis	J. B. Tyrrell
T. R. Drummond	Archer E. Wheeler
Robert J. Grant	Orvil R. Whitaker
Allen C. Hardison	George B. Wilson

Lewis Emanuel Young will be introduced as President of the Institute for 1949.

Technical Program

Detailed individual Branch and Division programs, ranging from practically final to somewhat tentative, may be found in the January issues of the three AIME monthly journals as follows:

Mining Engineering: Mining Methods, Health and Safety in Mines, Minerals Beneficiation Division, Coal Di-

vision, Industrial Minerals Division, Extractive Metallurgy Division, Mining Geology, Geophysics.

Journal of Metals: Institute of Metals Division, Iron and Steel Division, Extractive Metallurgy Division.

Journal of Petroleum Technology: Petroleum Division.

Programs of the Mineral Industry Education Division and the Mineral Economics Division appear in the following pages.

See chart on page 14 for schedule of all sessions.

Mineral Economics

Three papers are scheduled for the Tuesday afternoon session on mineral economics and it is hoped to have prominent national figures to present them. The first paper, "America's Stake in the Raw Materials of the World," will point out the tremendous importance of foreign sources of mineral supply to the United States and the need for a dynamic international program to assure a continuing flow of these vital raw materials to American industry. Since strategic materials and stockpiling are an important factor in this situation there should be substantial interest both on the part of Institute members and the general public in what the speaker has to say.

The second paper, entitled "The Future of Gold as a Base for the Monetary Systems of the World," will be presented by a monetary expert not identified with the gold mining industry. An analysis of past trends, the present situation, and the outlook for the future should be of value to the mining industry in general and particularly to that segment of the industry where gold production is an important source of revenue. As the third paper, "International Co-operation in Mineral Production under the Proposed Charter for the International Trade Organization of the United Nations" will deal with the future of cartel and other production-control agreements in the mineral field. The session is under the auspices of the Institute's new Mineral Economics Division.

MIED Program of Widespread Interest

All members of the Institute should look into the program of the Mineral Industry Education Division as there is something of interest to mining, metallurgy, geology, geophysics, and petroleum men. The usual Sunday afternoon and evening sessions will be held in the Hearst Mining Building on the University of California campus, Berkeley. They will be in the nature of forums: afternoon, on mining and metallurgy; evening, geology, geophysics, and petroleum. Two able moderators will lead the discussion: J. R. Van Pelt, Jr., in the afternoon, and E. DeGolyer in the evening. The speakers, men from industry, will have papers on present-day research problems in their own fields and possibly will indicate what the engineering curricula of the future should contain in order to answer better the problems of today and the future. Time will be allowed for discussion toward the end of each session.

A buffet supper at the Men's Faculty Club will follow the Sunday afternoon session.

The Division will hold a third session Monday morning and will meet at luncheon on Tuesday.

Student Forum, Tuesday afternoon.

The program follows (exact titles in final program):

Sunday Afternoon and Evening

Theme: Mineral Engineering Education of the future in the light of present-day research problems.

AFTERNOON SESSION—MINING AND METALLURGY

J. R. Van Pelt, Jr., moderator. C. E. Lawall, Coal Mining; J. H. Rahilly, Metal Mining; A. B. Cummins, Industrial Minerals; D. S. Eppelsheimer, Physical Metallurgy; also papers on Extractive Metallurgy and Mineral Preparation.

BUFFET SUPPER

EVENING SESSION—GEOLOGY, GEOPHYSICS, AND PETROLEUM

E. DeGolyer, moderator. Gustav Egloff, Petroleum Refining and Synthetic Fuels; G. C. Gester, Petroleum Geology; Morris Muskat, Production Research—Present and Future; A. C. Rubel, Production Engineering; W. H. Geis, The Professional Engineer; also paper on geophysics.

MONDAY MORNING

H. E. Nold, Registration of Engineers; J. P. Spielman, Metallurgy Courses; M. I. Signer, Mining Courses; J. D. Forrester, Graduate Study; W. B. Plank, Enrollment Statistics.

TUESDAY NOON

MIED luncheon and business meeting.

Petroleum Division

Four sessions and the annual dinner have been arranged. The production review, Monday afternoon, will consist of eight or nine regional presentations, both domestic and foreign. As at New York last February, these presentations will cover the high lights and exclude detailed statistical material. Tuesday morning will be devoted to economics and it is planned to review the California, national, Canadian, and world oil situations. Prominent and authoritative speakers will be listed in the final program. The two sessions on Wednesday will be on technology and the material in sight may make a session necessary on Thursday morning.

The principal speaker at the dinner on Tuesday evening will be Reese Taylor, president, Union Oil Co. of California. The dinner will be the occasion, too, for the presentation to F. Julius Fohs and J. B. Umpleby of the Division's Certificate of Service Award, which went last year to Earl Oliver, Fred Plummer, and Eugene Stephenson. At the dinner, I. W. Alcorn turns over the gavel to Lloyd Elkins, Chairman for 1949.

At the Sunday evening forum of the Mineral Industry Education Division, E. DeGolyer will act as moderator of the discussion on geology, geophysics, and petroleum. (See MIED program.)

The Institute Research Committee will meet at 4 p.m., Monday.

Robert Hoss will receive the Alfred Noble Prize at the banquet Wednesday evening, for his paper, "The Calculated Effect of Pressure Maintenance on Oil Recovery," published in *Petroleum Technology*, September, 1947.

Metals Branch

The Institute of Metals Division (ferrous and nonferrous physical metallurgy) will hold eight or nine

sessions running throughout the meeting; among them, sessions on properties, plastic flow, grain growth and texture, and phase diagrams, three powder metallurgy sessions, a general session, a sintering symposium, and a sintering seminar. Early in the week the Iron and Steel Division will hold four sessions, among them sessions on steelmaking and sulphur in the coke oven and blast furnace. It will also meet with the Minerals Beneficiation Division at the session on pyrolysis and agglomeration and with the Extractive Metallurgy Division on the smelting of titanium ores.

The Metals Branch luncheon (IMD, ISD, and EMD) will be held Tuesday. The Institute of Metals Division Annual Award will be announced at the banquet. The paper for which the award is made this year appears in *Metals Technology*, October, 1946, and is entitled "An Electron Diffraction Study of Oxide Films Formed on Iron, Cobalt, Nickel, Chromium, and Copper at High Temperatures"; authors, E. A. Gulbransen and J. W. Hickman (deceased).

The Annual IMD lecture will be delivered Tuesday morning (11 a.m.) by Egon Orowan, of Cambridge University.

The Howe Memorial Lecture by John Chipman, head, department of metallurgy, MIT, is scheduled for Wednesday morning at 11 o'clock.

Research

The Institute Research Committee, Elmer R. Kaiser, Chairman, will meet at 4 o'clock, Monday.

PAIMEG

The United States Section, Pan-American Institute of Mining Engineering and Geology, will meet at luncheon on Wednesday. Coking possibilities in Colombia may be a topic of discussion.

Mining Methods

Appropriately — in harmony with the Centennial celebration of the California gold rush—the initial paper (Monday afternoon) is "One Hundred Years of Placer Gold Mining in California," by Herbert A. Sawin. The papers—there are six sessions—run the gamut of mining subjects: alluvial mining, opencut mining, drills and drilling, sublevel stoping, caving operations, dump leaching, pumping, etc. A feature is the eight-paper symposium on phosphate mining on Wednesday morning. At the luncheon that day, motion pictures of the old Cornish engines in England will be shown.

Health and Safety in Mines

Monday morning session, avoiding conflict with Mining Methods, four papers, among them, "Safety in Mining at the Andes Copper Mining Company," by Charles M. Brinckerhoff.

Minerals Beneficiation Division

As an appetizer before contemplating the huge technical repast of the MBD, may we suggest the Wednesday afternoon (Noralyn) session, at which will be described the many innovations at the largest and most modern plant of its kind ever built, namely the new phosphate washery of the International Minerals and Chemical Corp., at Mulberry, Fla. Now for the entire bill, by sessions:

Monday morning, coal preparation, Coal Division supplying the program; afternoon, grinding; Tuesday morning, flotation practice; afternoon, flotation theory; afternoon with ISD, pyrolysis and agglomeration; Wednesday morning and afternoon, hydrometallurgy; Wednesday afternoon, jointly with Industrial Minerals Division, Noralyn washery; Thursday morning, gravity separation; Thursday afternoon, "cleanup" session; same afternoon, meeting of Research Committee on Comminution.

The ladies are welcome at the MBD luncheon on Tuesday.

Coal Division

A special three-session symposium on coal preparation, and three sessions on coal-mining problems. The general theme is geared to the growing industrial development of the West and the function of coal in this picture. (Annual luncheon, Tuesday.)

Space does not permit a general survey of six sessions so let's spotlight here and there. Take Monday afternoon: G. A. Vissac, prominent consulting engineer of Vancouver, B. C., will discuss the heat-drying of coal in its technical aspects. The removal of bed moisture from the fine sizes of subbituminous coals in fluidized condition at high capacities will be discussed by V. F. Parry and associates. W. M. Bertholf and J. D. Price will describe a well-tried installation of six vibrating filters for coal sludge which have operated at the Pueblo washery since 1936. So successful has the installation been that it has saved 1400 operating shifts in the washery in the past twelve years, equivalent to a gain of about 2,000,000 tons in production.

Two more quick shifts of the spotlight before the make-up man's scissors start cutting: Tuesday morning session—Another means of clarifying coal-washery water will feature the Dutch cyclone in the opening paper. So successful has been the installation of an experimental but full-size cyclone thickener at the Shamrock, W. Va., mine of the Truax-Traer Coal Co., that several other cyclones have been ordered. This paper is by Thomas Fraser, R. L. Sutherland, and F. F. Giese. Tuesday afternoon, coal mining problems; e.g., trackless mining on steeply pitching thick coal beds in Wyoming, H. C. Livingston, narrator. Wednesday morning, George Hess will show how aerial photography helps in preparing contour maps for strip mines. Coal mining in our nearest-to-Russia frontier in Alaska will be discussed Wednesday afternoon by Albert J. Toenges.

Extractive Metallurgy Division

Five sessions: See chart.

Featured Monday afternoon is a group of three papers concerned with cadmium technology. G. T. Smith and R. C. Moyer describe the fire metallurgy of cadmium; G. H. Anderson describes the electrolytic cadmium practice at Risdon; and P. C. Federsen and Harold E. Lee cover cadmium recovery practice in lead smelting.

Tuesday morning, A. A. Collins reviews the effect of high copper content on the operation of the blast furnace; R. R. McNaughton and associates give results of their experiments with oxygen-enriched air both in the lead blast furnace and in the slag fuming furnace; W. S. Reid discusses sintering practice at the Selby

Smelter; and roasting developments are described in detail by J. A. B. Forster.

Wednesday morning: A three-hour round table discussion on blast-furnace charge preparation and dross treatment, organized by R. R. McNaughton. Casper Nelson will lead off with charge preparation and A. A. Collins will keynote the discussion on dross treatment.

Wednesday afternoon: H. R. Page and A. E. Lee, Jr., trace the development of the modern silicon carbide retorts from the old clay retort; R. R. Furlong and Donald Wertz describe the development of a controlled drying process for zinc retorts at Donora Zinc Works; G. E. Johnson, the development of muffle furnaces for the production of zinc oxide and zinc at East Chicago, Ind.; and T. J. Woodside describes the El Paso slag treatment plant.

The Division meets jointly with the Industrial Minerals and Iron and Steel Divisions Thursday morning for four papers on titanium metallurgy.

Thursday afternoon: Copper; aluminum.

The EMD will join with the IMD and ISD at the annual Metals Branch luncheon on Tuesday.

Industrial Minerals Division

Program somewhat tentative as to distribution of a long partial list of papers (27 at this writing) among eight sessions clearly defined as follows: Monday, resources of the industrial minerals field; afternoon, mineral economics; Tuesday morning, structural materials; afternoon, new products, processes, and techniques; Wednesday morning, jointly with Mining Methods Committee, phosphate symposium; afternoon, jointly with Minerals Beneficiation Division, four Noralyn washery papers; Thursday morning, geology of industrial minerals; Thursday morning, jointly with EMD and ISD, titanium.

Executive Committee meeting, 5 p.m., Tuesday.

Division luncheon, Wednesday noon.

Mining Geology

The Mining Geology Committee and the Society of Economic Geologists meet together for four sessions —Tuesday and Wednesday morning and afternoon. The Committee also meets at luncheon Tuesday noon and the annual dinner of SEG is that evening.

The first two sessions follow an "ore-finding" theme. S. G. Lasky opens with an appraisal of our national mineral resources and there follow papers on the broader features of ore finding and engineering aspects of mineral exploration. H. C. Gunning and Roger H. McConnell will describe the role of certain structural controls in the formation of ore deposits in British Columbia and in the Coeur d'Alene district of Idaho, and Paul F. Kerr and Bronson Stringham will describe alteration effects associated with ore formation in the Silver Bell, Ariz., and Bingham, Utah, districts. R. F. Helmke will review some of the recent outstanding Western iron ore developments and J. J. Collins will describe the important role played by the copper industry in Japan.

To start off the Wednesday morning session, Reno Sales and Charles Meyer, whose paper on the vein alteration at Butte was outstanding at the Annual Meeting last February, are expected to repeat their fine presentation with a paper on the vein formation at Butte. Also on the agenda are descriptions of the Saddle Reef deposits of Bendigo, Australia, and descriptions of four important mining districts in the United States. The Wednesday afternoon session will feature six papers on atomic mineral deposits.

An exhibition of radioactive minerals together with various laboratory and field Geiger counters is planned.

Geophysics

Two sessions: Thursday morning and afternoon.

Atmospheric conditions above the Arctic Circle are much different from those in lower latitudes, with schedules laid down for operations at midnight in summer and hardly one hour with daylight in winter. This is apropos of the paper by Hans Lundberg on aerial magnetic surveys above the Arctic Circle. Dr. Lundberg will show some interesting pictures. Another paper, by Oscar Weiss, reports results with the aerial magnetometer in South Africa. Henry Faul's paper on radioactivity exploration with Geiger counters is in the November *Mining Technology*.

Woman's Auxiliary, AIME

FEBRUARY 13-17

Ladies' Entertainment Committee

Honorary Chairmen

Mrs. William E. Wrather
Mrs. Lewis E. Young

Mrs. H. Robinson Plate, *Chairman*
Mrs. Carlton D. Hulin, *Vice-Chairman*

Registration—Mrs. Granville Borden

Section Reports—
Mrs. Herman A. Prosser

Round Table—Mrs. Newell G. Alford

Membership—Mrs. Henry Y. Eagle

Reception Committee

Mrs. Newell G. Alford
Mrs. W. Sprott Boyd
Mrs. Clifford Bowie
Mrs. Worthen Bradley
Mrs. A. G. Cadogan
Mrs. Frank Girard
Mrs. George L. Harrington
Mrs. W. W. Henry
Mrs. James F. Kemp
Mrs. Jules Labarthe
Mrs. William Wallace Mein
Mrs. William Wallace Mein, Jr.
Mrs. James G. Parmelee
Mrs. A. B. Parsons
Mrs. Herbert A. Sawin
Mrs. J. H. Sampson
Mrs. O. Cutler Shepard
Mrs. George Sibbett
Mrs. Fred W. Varney
Mrs. D. N. Vedensky
Mrs. Livingston Wernecke

The tentative program follows:

MONDAY

Registration, Fairmont Hotel.
All-Institute Luncheon.
Evening Informal Dinner Dance.

TUESDAY

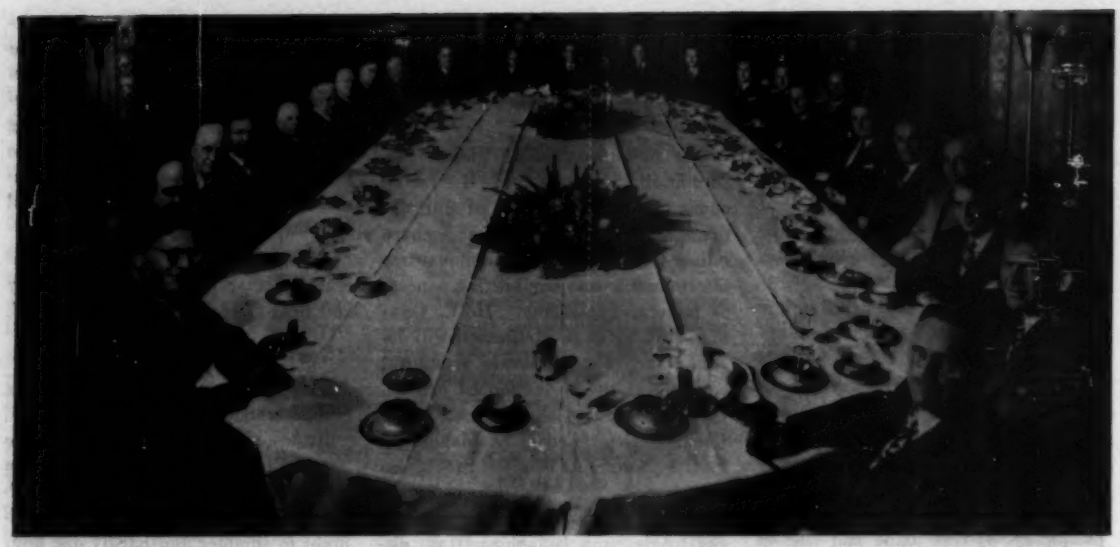
9:45 a.m. Annual Business Meeting.
12:30 p.m. Luncheon. Top of the Mark, after business meeting.
2:30 p.m. Leave by bus from Hotel for tea at Mrs. W. W. Mein's residence in Woodside.
Evening: No planned entertainment.

WEDNESDAY

9:45 a.m. Annual Round Table discussion, Fairmont Hotel; Chairman, Mrs. Newell G. Alford.
12:30 p.m. Luncheon and Fashion Show at St. Francis Yacht Club.
Evening: AIME Banquet. Palace Hotel.

Student Forum Proposed

Because of the success of a young engineers' and students' round table at the El Paso Regional Meeting, a similar session is planned for the Annual Meeting, on Thursday afternoon. Here is a chance for *would be's* to ask questions like: How much will I make on my first job as a mining engineer? Should I work for an advanced degree? What kind of training programs do the companies have? Why don't the mining companies pay as much to recent graduates as the petroleum people do?



Annual Meeting planners gathered at the Pacific Union Club, San Francisco, on Dec. 7 to forward arrangements for the February meeting. Counter clockwise, they include: E. H. Wisser, R. D. Moody, L. A. Parsons, O. P. Jenkins, L. A. Cranson, D. H. McLaughlin, E. L. Oliver, Worthen Bradley, L. C. Uren, W. L. Penick, H. N. Appleton, W. W. Mein, Jr., W. C. Collyer, G. H. Playter, Gilfry Ward, H. A. Sawin, Gordon Gould, P. R. Bradley, Jr., R. M. Searls, H. N. How, S. H. Williston, R. E. Byler, Bernard York, and L. B. Wright.

Setting Up for the Big Blast

Many San Francisco AIME members took a week off from their normal pursuits early in December to meet with Newell Appleton from AIME Headquarters to drive the final wedges in the Annual Meeting setup. It will be your fault if the machine isn't oiled by your making advance hotel reservations and purchasing tickets to social functions. You will want all the time you can get for drilling on Feb. 14 to 17, so clean your working place now so you can make her pay then. San Francisco carries the *lode;* your job is to be set up to start drilling when the air is turned on and to blast before you go off shift. Shift Boss Appleton is preparing a notice to be sent to all AIME members in the United States, Canada, and Mexico which contains full information on how to fill your oil bottle with hotel reservations, advance registration, and tickets to social affairs. You can secure your stope by making out your check to the AIME Housing Bureau, Room 200, 61 Grove St., San Francisco, $5 for one person, $10 for two.

Mrs. H. R. Plate, Mrs. C. D. Hulin, and Mrs. Worthen Bradley, of the Woman's Auxiliary, lunched at the Fairmont on Dec. 8 with H. N. Appleton and (standing) Walter Penick, G. H. Playter, Worthen Bradley, and W. W. Mein, Jr., and made plans for Annual Meeting activities.

Don't just bring your digging clothes because there is going to be an Informal Dinner Dance on Monday night in Peacock Court of the Mark Hopkins, tickets $7.50 each; a Stag Smoker at the Commercial Club on Tuesday night at $10 apiece; and on Wednesday, the Annual Banquet at the Palace Hotel, also for $10. Full lunch buckets will be provided at various Divisional and Committee luncheons. If things get too tough underground, you can take to the air for a field trip around the Bay industrial area in a Pan American airplane. The only charge for this trip will be for transportation to the airport. On Friday at 8 a.m. a field trip will leave for the San Andreas fault; tickets are $5 per person.

The ore body has been delimited, all we need now is the miners to break the rock. We'll see *you* at San Francisco.

Book Reviews

Price Control in the Metal Industries

The History of Basic Metals Price Control in World War II. By Robert F. Campbell. Columbia University Press. 1948. 263 p. $3.25.

REVIEWED BY SIMON D. STRAUSS

Robert Campbell has diligently assembled a lot of facts about the history of price control during World War II as it affected the iron, steel, and nonferrous metal producers. It does not make exciting reading, possibly because the facts themselves are not too exciting, although at the time there undoubtedly were a good many people who worked up a great deal of high blood pressure over some of these controls.

As is to be expected from an official historian of the OPA, the conclusions are generally favorable to the Office of Price Administration, and the author feels in fact that if any error was made it was on the side of liberality by OPA in allowing price increases, particularly in the steel industry. Professor Campbell apparently is not too well acquainted with the mining and metal industries themselves, for his text gives repeated evidence that he suffers under the customary layman's inability to distinguish between ore and metal. Thus he speaks for instance of several sources of imported ores as being Chile for copper, Mexico for lead, and Mexico, Peru, and Belgium for zinc. Substantially all of our imports of Mexican lead are in the form of metal and not of ore, and, of course, Belgium produces no zinc ore, being an importer of ore and an exporter of metal.

A great deal of attention is paid to the premium price plan, which was largely evolved by OPA officials. Professor Campbell makes much of the fact that this plan had to be literally forced down the unwilling throats of the WPB and the RFC. He refers to the plan as being intended to maintain and expand production of copper, lead, and zinc without greatly increasing the general level of prices, but when he discusses the results of the plan he fails to point out that actually production decreased in all three of the metals from the 1942 level, when the plan went into effect, through the end of the war. Of course, this was not necessarily the plan's fault, since primarily the drop in production reflected a shortage of labor.

On the whole, the book is of value primarily to persons contemplating the re-establishment of price controls in the metal industries in the event of a future war. It is to be hoped, therefore, that it will rest long, comfortably, and undisturbed on the book shelves.

Industrial Air Sampling and Analysis

Veterans and newcomers in the field of industrial hygiene now have recourse to a reference manual, "Industrial Air Sampling and Analysis," by Leslie Silverman, that covers the latest developments on the control of contaminants in workroom air.

The Industrial Hygiene Foundation has just issued this bulletin for the benefit of its member companies, industries interested in advancing employe health and improving working conditions.

Nonmember companies and individuals may order the bulletin for $1.50 from the Foundation's headquarters, 4400 Fifth Ave., Pittsburgh 13.

What Went on at Recent Local Section Meetings

SECTION	DATE	PLACE	PRESIDING OFFICER	ATTENDANCE	SPEAKER, AFFILIATION, AND SUBJECT
Arizona, Ajo Subsection	Nov. 11	Ajo	William Keener	15	John Prendergast, power-plant superintendent, New Cornelia Branch, Phelps Dodge Corp. Discussion of Ajo Power Plant (Phelps Dodge).
Boston	Nov. 1	Smith House, Cambridge	George P. Swift	46	Roscoe J. Whitney, consulting engineer, Leominster, Mass. Hunting Pegmatites from the Air.
Carlsbad Potash	Oct. 22	Carlsbad	R. H. Allport	70	William E. Wrather, director, U. S. Geological Survey. Oil Production in the Middle East.
Carlsbad Potash	Nov. 18	Carlsbad	R. H. Allport	70	T. M. Cramer, vice-president, U. S. Potash Co. Early Developments in the Potash Basin.
Chicago	Nov. 3	Chicago Bar Assn.			Claudia Boyington, editor, industry relations section, *Ceramic Industry*. History and Production of American China.
Detroit	Nov. 22	Detroit		100	F. N. Rhines, Carnegie Institute of Technology. Sintering of Metal Powders.
Lehigh Valley	Nov. 5	Hotel Bethlehem	M. L. Fuller	60	Sherwin F. Kelly, S. F. Kelly Geophysical Services. Geophysics—Twentieth Century Treasure Hunting.
Mid-Continent	Nov. 8	Tulsa	J. Murray Walker	30	Clark Millison, consulting geologist. The Core Recorder. Henry Schaefer, Stanolind Oil and Gas Co. Limestone Pore Space Studies.
New York	Nov. 16	Mining Club			William E. Wrather, director U. S. Geological Survey. Some Aspects of Our Future Mineral Supply Problem.
Ohio Valley	Nov. 3	Engineers Club, Dayton	William A. Mueller	100	Donald B. Gillies, vice-president, Republic Steel Corp. The Future of Iron Resources.
Southwestern New Mexico	Oct. 13	Bayard Lions Club	Ira L. Wright	45	Reports on A. M. C. Convention papers.
Southwestern New Mexico	Nov. 17	Bayard Lions Club	Ira L. Wright	45	Staff members, U. S. Smelting Refining and Mining Co. The Pachuca and Real del Monte Districts of Mexico.
Southwest Texas	Nov. 17	Corpus Christi	Raoul J. Bethancourt	146	H. M. Cooley, Bethlehem Steel Co. Casing Design Brought Up to Date.
Tri-State	Nov. 12	Picher	O. W. Bilharz	53	J. G. Evans, Gardner-Denver Co. Travelog of Africa.
Utah	Oct. 14	Salt Lake City	W. C. Page	87	T. P. Billings, manager of mines, U. S. Smelting Refining and Mining Co. History of Metal Mining and Mine Operators in Utah.
Utah	Nov. 18	Salt Lake City	J. C. Landenberger, Jr.	51	James R. Richardson, manager Utah Mining Assn. Significant Developments in the Mining Industries' Labor Relations Field.

Among the Student Associates

Colorado School of Mines

Herman Knight was given the President's gavel, to keep for a year, at the Oct. 28 meeting of the Student Chapter at the Colorado School of Mines. Other new officers are: Bill Baker, Secretary-Treasurer; T. A. Hoy and Jack Dempsey, Directors; and George W. Heim, Faculty Sponsor. The members also appointed several committees, giving each at least one senior and one underclassman. Then, under the new leaders, the group outlined a membership drive that should make the Chapter the largest in the country.

The Nov. 18 session of the Student Chapter mixed business with social activities, thereby attracting 112 members. L. W. LeRoy, associate professor of geology at the School, spoke, with colored slides, on the general geology of the Lake Maracaibo region of Venezuela. When finished, Dr. Le Roy was asked questions on foreign employment, as he has had several years' experience working abroad. —*Harvey W. Smith, Public Relations Chairman.*

University of Nevada

Business was dispensed with at the Nov. 3 meeting of the Crucible Club, and Martin K. Hannifan took over for the evening. He is a 1938 graduate of the University's Mackay School of Mines, who recently returned to the States after working as a safety engineer for the Andes Copper Mining Co., in Chile. His talk on foreign jobs, a subject of great interest to his listeners, covered the advantages and disadvantages. An informal question and answer session followed. —*William D. Williams, Secretary.*

Missouri School of Mines

Almost 200 men got together for the Missouri School of Mines Student Chapter meeting on Nov. 10. The feature of the meeting was Burr Aton, of the Eagle-Picher Co., who presented his multitudinous audience with a talk and film on hygiene in mining and smelting. Mr. Aton discussed health protection for the workers, emphasizing silicosis and dust control. Refreshments followed.—*Albert Jones, Secretary.*

Ohio State University

As the 1948 part of the current school year drew to a close, students in the Mineral Industries Society of Ohio State University had already gone quite a ways in reaching their objective of an active and educational year. At the opening meeting, D. J. Demorest, retiring head of the department of metallurgy, spoke on "How Not to Be a Metallurgist." The other meetings consisted of a movie, "Wealth of the Andes," the introduction of new members, and business. In addition, a vigorous athletic program, directed by William H. Santschi, was started. All these activities were maneuvered by the new officers: Benjamin Roth, President; Thomas L. Chase, Vice-President; and John A. Schumann, Secretary-Treasurer.

At an organization meeting on Oct. 26, the students of petroleum and mining engineering at the Ohio State University formed the Prospectors' Club. Its purpose is to promote a joint understanding of the diversified interests of the petroleum and mining industries. Benson D. Blackie and Hartzel C. Slider were chosen as President and Vice-President respectively.

Yale University

The Yale Metallurgical Society Student Associates, numbering 25, elected their present officers and cast up a whole year's schedule at their Nov. 4 meeting. The returns of the election made D. A. Nankivell President, Harold Margolin Vice-President, V. T. Potter Secretary, and C. H. Stokesbury, Jr., Treasurer. In line with the plans arranged at that meeting, two weeks later members of the Society inspected the foundry of Sargent & Co., at New Haven.—*V. T. Potter, Secretary.*

Calendar of Coming Meetings

JANUARY

5 Chicago Section, AIME.
6 Reno Branch, Nevada Section, AIME.
7 Columbia Section, AIME.
10 Mid-Continent Section, AIME.
10 Boston Section, AIME. President W. E. Wrather.
10-14 Society of Automotive Engineers, annual meeting and engineering display, Book-Cadillac Hotel, Detroit.
11 East Texas Section, AIME.
12 El Paso Metals Section, AIME.
12 San Francisco Section, AIME. R. A. Kinzie, Jr., on the Lepol kiln.
12 Southwestern New Mexico Section, AIME.
17 Detroit Section, AIME. Thermodynamics.
17 Minnesota Section, annual meeting, Hotel Duluth, Duluth, Minn.
18 Gulf Coast Section, AIME.
18 Washington, D. C., Section, AIME.
18-19 Symposium for Mining Engineers, University of Minnesota.
19 Southwest Texas Section, AIME.
20 Mineral Industry Institute, 22nd annual meeting, sponsored by School of Mineral Engineering, Univ. of Washington, Seattle. Joint evening session with North Pacific Section, AIME.
20 Carlsbad Potash Section, AIME.
20 North Pacific Section, AIME.
20 Utah Section, AIME.
21 Oregon Section, AIME.
24 Alaska Section, AIME.
24-28 American Society of Heating and Ventilating Engineers, annual meeting, Chicago.
25 Montana Section, AIME.
Jan. 31-Feb. 4 AIEE, winter general meeting, Pennsylvania Hotel, New York City.

FEBRUARY

1 Society for Applied Spectroscopy, 63 Park Row, New York City, 8 p.m. F. Nolan, on fluorescence.
2 Chicago Section, AIME. S. J. Cresswell, on the Bessemer process.
3 Reno Branch, Nevada Section, AIME.
4 Columbia Section, AIME.
7 Boston Section, AIME.
8 East Texas Section, AIME.
9 El Paso Metals Section, AIME.
11-12 Association of American State Geologists, San Francisco.
11-12 New Mexico Miners and Prospectors Assn., Santa Fe.
14 Mid-Continent Section, AIME.
15 Gulf Coast Section, AIME.
15 Washington, D. C., Section, AIME.
14-17 Annual meeting, AIME, Fairmont Hotel, San Francisco.
Feb. 28-Mar. 4 ASTM, spring meeting and committee week, Hotel Edgewater Beach, Chicago.

MARCH

3-5 Symposium on Southeast mineral resources, University of Tennessee, Knoxville.
10-12 American Physical Society, Div. of Solid State Physics, Hollenden Hotel, Cleveland.
14-17 American Association of Petroleum Geologists, annual meeting, Hotel Jefferson, St. Louis.
Mar. 29-Apr. 1 Annual Safety Convention and Exposition, Hotel Pennsylvania, New York City.

APRIL

18-20 Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Palmer House, Chicago.
24-28 American Ceramic Society, national meeting, Netherland-Plaza, Cincinnati, Ohio.

SEPTEMBER

25-28 Regional Meeting, AIME, Neil House, Columbus, Ohio.

OCTOBER

17-19 Institute of Metals Division, AIME, fall meeting, Cleveland.

FEBRUARY 1950

12-16 Annual Meeting, AIME, Pennsylvania (Statler) Hotel, New York City.

APRIL 1950

10-12 Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Netherland-Plaza Hotel, Cincinnati.

Current Institute Papers

The following papers in the Institute monthly journals are available to members according to classification of the papers and the expressed desire of the members for the respective journals. Other members may obtain papers by purchasing the indicated issue of the journal at $0.75 per copy. There are no separate copies of the individual papers.

Mining Papers

The Ammonium Sulphate Process for the Extraction of Alumina from Clay and Its Application in a Plant at Salem, Oregon—By W. R. Seyfried. (*September Mining Technology* and *December Metals Technology.*)

A Process: Using Clay, Sulfuric Acid, and ammonia for the extraction of metal grade alumina. This installation was sponsored by the United States Government for the purpose of finding a substitute for bauxite as a source of alumina for aluminum production.

Radioactivity Exploration with Geiger Counters—By Henry Faul. (*November Mining Technology.*)

A Survey of the General Principles, recent practice, and new developments in geophysical exploration with radiation counters, as applied to the problems of surface and underground activity measurement, borehole logging, and sample analysis of radioactive rocks and ores.

The Occurrence and Mining of Solid Bitumens in Western Argentina—By Howard A. Meyerhoff. (*November Mining Technology.*)

Asphaltite Is Being Mined as Solid fuel in small quantity in Mendoza and Neuquén in west-central Argentina. The industry is handicapped by remote location and by costs that may make it noncompetitive with imported coal. Survival may depend upon development of a chemical industry utilizing the asphaltite as a raw material.

Determination of Room and Pillar Dimensions for the Oil Shale Mine at Rifle, Colorado — By Fred D. Wright and Philip B. Bucky. (*November Mining Technology.*)

This Paper Describes the Method used for determining the safe room and pillar dimensions for the oil shale mine. The work consisted of a study of the structure of the deposit; determination of the physical properties of the rocks; and centrifugal tests on scale models of the roof and pillars.

Some Postwar Problems of Geological Engineering Education—By W. T. Thom, Jr. (*November Mining Technology.*)

Geological Engineers Having Exceptional ability and thorough training are being called by the oil and mining companies in ever-increasing numbers.

These requirements probably cannot be met hereafter unless (a) the schools continually improve their "co-op" programs, and (b) unless the schools, the mineral industries, *and the professional societies* interested, see to it that the able high school students, who are "naturals" for geoexploratory work, get suitable orientation and advice before their senior year of high school.

A Review of Rock Pressure Problems—By Richard P. Schoemaker. (*November Mining Technology.*)

A Review Is Presented of Some Important results of recent research on the rock pressure phenomenon.

Photoelastic model experiments and mathematical analysis throw a new light on the mechanism of rock failure and doming in underground openings. Mathematical analysis also gives a new approach to the problems of subsidence and of "flow" of rocks under high stress.

Petroleum Papers

Stresses Around a Deep Well—By A. J. Miles and A. D. Topping. (*November Petroleum Technology.*)

In This Paper the Theory of Elasticity has been applied to the rock about a deep well. When the physical properties of the rock and the state of stress existing therein before drilling can be determined or assumed, it is possible to determine analytically the stress concentrations in the rock about the borehole.

Effect of Antifreeze Agents on the Formation of Hydrogen Sulphide Hydrate—By D. C. Bond and N. B. Russell. (*November Petroleum Technology.*)

The Effects of Various Antifreeze agents on the formation of hydrogen sulphide hydrate have been studied. On a molar basis, the relative lowering of T_M (maximum temperature at which solid hydrogen sulphide hydrate can exist in equilibrium with the given solution) is given for various agents.

Gravity Drainage Theory—By W. T. Cardwell, Jr., and R. L. Parsons. (*November Petroleum Technology.*)

The Paper Presents a Theory for estimating the rate of gravity drainage of a liquid out of a sand column. Account is taken of the variation in permeability to the liquid as the saturation in the upper part of the sand becomes less than 100 per cent. The theory is confirmed by previously published data.

Revaporization of Butane and Pentane from Sand — By C. F. Weinaug and J. C. Cordell. (*November Petroleum Technology.*)

Data Are Presented for the Pressure depletion of methane-n-butane and methane-n-pentane mixtures from an unpacked and a sand-packed constant-volume cell. The results indicate that the P-V-T equilibrium of these systems is not affected by the presence of sand.

The Effect of Permeability Stratification in Cycling Operations—By Morris Muskat. (*November Petroleum Technology.*)

Assuming Idealized Reservoir Stratification, cycling recoveries are calculated for exponential, probability, and linear permeability distributions. Break-through recoveries are computed for different degrees of permeability variation, and the total wet gas recoveries and associated total gas throughflows until the wet gas content of the flow stream falls to preassigned limits.

The Theory of Potentiometric Models—By Morris Muskat. (*November Petroleum Technology.*)

The Analytical Theory Underlying potentiometric models as analogues of reservoir flow systems is given. The manner of constructing models to simulate systems of variable thickness, permeability, porosity, and fluid density is outlined. It is concluded that isovol models adjusted for variable hydrocarbon porosity will not give correct analogies to actual reservoir fluid motion.

Coal Papers

Oil and Gas Wells Drilled through Workable Coal Seams—By A. J. Alexander. (*November Coal Technology.*)

The Paper Presents the Dangers that existed when mining coal in the vicinity of uncharted wells prior to the enactment of the Oil and Gas Laws of W. Virginia and the application of these laws, under the direction of the Department of Mines, which tend to safeguard lives and property of the State's two major industries.

The Use of Illinois Coal in the Production of Metallurgical Coke—By F. H. Reed, H. W. Jackman, and P. W. Henline. (*November Coal Technology.*)

An Experimental Coke Oven Has been developed by the authors in which coal blending may be studied. Coking results may be applied directly to com-

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mercial oven practice. Studies have shown that prepared coals available from the Illinois field may be used to advantage in modern ovens producing metallurgical coke for blast furnace fuel.

Cleaning Anthracite Silt for Boiler Fuel with Humphreys Spiral Separator — By W. L. Dennen and V. H. Wilson. (*November Coal Technology.*)

THE PAPER DESCRIBES THE FIRST Anthracite silt cleaning plant using the Humphreys spiral separator, and the results obtained in the first year's operation.

Determination of Petrographic Components of Coal by Examination of Thin Sections—By B. C. Parks and H. J. O'Donnell. (*November Coal Technology.*)

THIS PAPER REVIEWS THE BUREAU'S terminology of describing components of coal and type classification of coals from microscopic analysis. It describes experimental tests to determine accuracy achieved in making petrographic analyses of coal by thin-section microscopy and presents data summarizing results. The practical application of analyses of coal by microscopic method is discussed.

Coal Dock Operations of the North Western-Hanna Fuel Co. at the Head of the Lakes—By J. T. Crawford. (*November Coal Technology.*)

THIS PAPER, WHICH INCLUDES A BRIEF history of coal dock operations, is largely devoted to a description of operating practices and problems of five coal docks at the ports of Duluth, Minn., and Superior, Wisc. Included are general details of moveable bridges, their associated screening plants and other equipment required for the unloading of bulk coal carriers, the storage on the docks, and the preparation and reloading of coals for distribution by rail and truck into the area serviced by the Lake docks.

Metals Papers

Temper Brittleness of Plain Carbon Steels—By L. D. Jaffe and D. C. Buffum. (*December Metals Technology.*)

IT IS SUGGESTED THAT PLAIN CARBON steels are susceptible to temper brittleness, and that temper brittleness develops so rapidly in these steels that even drastic quenching from a high tempering temperature is insufficient to suppress it. Limited experimental results support this theory.

Hydrogen in Aluminum—By Y. Dardel. (*December Metals Technology.*)

SUGGESTION OF A NEW METHOD TO Determine the amount of dissolved hydrogen in liquid as well as in solid metal has been made. The sample is first melted if solid, then held at constant temperature, and the hydrostatic pressure above is slowly lowered. When the first bubble appears, the pressure is read and a nomogram gives the corresponding hydrogen amount. The solubility of hydrogen in solid aluminum is very small. It varies from 0.058 cm^3/100 g at 659C to about 0.015 cm^3/100 g at 550C.

Lead-grid Study of Metal Powder Compaction—By Robert Kamm, M. A. Steinberg, and John Wulff. (*December Metals Technology.*)

WITH THE AID OF CIRCULAR-HOLED lead grids, it is shown in the present paper that the compaction of metal powder compacts is primarily aided by die wall lubrication. High pressing speeds and vacuum pressing do not appreciably affect green density but may influence sintered density.

Morenci Smelter of Phelps Dodge Corp., Morenci, Arizona—By L. L. McDaniel. (*January Journal of Metals.*)

OPERATING PRACTICE OF THE NEW Morenci smelter, Morenci, Ariz., has never been described, and it is the purpose of this paper to discuss metallurgical and operating practice and to describe structural features of the completed plant and to show drawings, photographs, and tabulations of the results in support of the article.

The Interaction of Liquid Steel with Ladle Refractories—By C. B. Post and G. V. Luerssen. (*January Journal of Metals.*)

THE CLEANNESS OF BASIC ARC MELTED steel is influenced by the manganese and silicon contents. The reaction of liquid steel with ladle refractories, and subsequent contamination of ingots with nonmetallics, account for this effect. Cleaner steel can be obtained if the manganese and silicon contents are made substantially equal.

The Influence of Temperature on the Affinity of Sulphur for Copper, Manganese, and Iron—By E. M. Cox, M. C. Bachelder, N. H. Nachtrieb, and A. S. Skapski. (*January Journal of Metals.*)

EQUILIBRIUM CONSTANTS OF THE REACtions *Metal Sulphide* + H_2 = H_2S + *Metal* were measured. The affinity of sulphur for copper is greater than that for iron and exceeds that for manganese above 1350C. It is concluded that increasing amounts of copper in scrap raise the sulphur content of the bath in the open-hearth process.

Plastic Deformation Waves in Aluminum—By Andrew W. McReynolds. (*January Journal of Metals.*)

PLASTIC DEFORMATION IN ALUMINUM alloys is found to occur not continuously, but by the repeated propagation of plastic waves. The resulting stress-strain curve consists of regularly spaced rectangular steps. The effect results from the presence of alloying elements, probably by precipitation, and occurs only within a range of temperatures.

On the Structure of Gold-silver-copper Alloys—By J. G. McMullin and J. T. Norton. (*January Journal of Metals.*)

THE CONSTITUTIONS OF A NUMBER OF gold-silver-copper alloys were investigated by X-ray diffraction methods. A two-phase field was found to extend from the silver-copper binary into the ternary system as far as the 75 weight per cent gold alloys. The equilibrium limits of this two-phased region are outlined at several temperatures.

Stress and Strain States in Elliptical Bulges—By C. C. Chow, A. W. Dana, and G. Sachs. (*January Journal of Metals.*)

THE STRESS AND STRAIN STATES FOUND in two elliptical bulges and one circular bulge contour of cartridge (70-30) brass were analyzed. The strains were determined experimentally while the stresses were calculated by using the equation for equilibrium of a shell and several laws of plasticity. In addition the several universal stress-strain relations were studied.

A Study of Textures and Earing Behavior of Cold-rolled (87-89 Per Cent) and Annealed Copper Strips—By Ming-Kao Yen. (*January Journal of Metals.*)

THIS PAPER DEALS WITH THE TEXTURES and deep-drawing properties of five types of commercial copper strips after 87 to 89 per cent final reduction and annealing. The influence of impurities, especially phosphorus, is given particular attention. A correlation between the formation of textures and earing behavior is reported.

Use of Electrical Resistance Measurements to Determine the Solidus of the Lead-tin System —By Ralph Hultgren and Stanley A. Lever. (*January Journal of Metals.*)

A METHOD OF DETERMINING THE solidus of an alloy by means of electrical resistance measurements taken under equilibrium conditions at successively higher temperatures is described. The method was found to be convenient, reproducible, and highly sensitive. The results agree closely with those of other observers.

Transient Plastic Deformation—By R. P. Carreker, J. G. Leschen, and J. D. Lubahn. (*September Metals Technology.*)

EXPERIMENTS PERFORMED WITH LEAD, copper, and an aluminum alloy qualitatively confirm predictions made in the preceding paper of transient effects in deformation. The effects of sudden changes in stress, temperature, and strain rate, and of cyclic loading are considered.

XUM

News of AIME Members

Don U. Deere is on leave of absence from the University of Puerto Rico and is doing graduate work in geology at the University of Colorado, Boulder.

Alfred S. Geldman, who had been resident engineer in charge, American Silver Corp., Los Angeles, is now assistant superintendent of the Monolith Portland Cement Co., Monolith, Calif.

T. S. Lovering, of the U. S. Geological Survey, delivered a lecture at the University of Kansas on Nov. 22 on "The Drive for Minerals."

W. W. Taylor has been with Stone & Webster since his return from Chile and is now in charge of their work on the construction of the Texas Gas Transmission Corporation's gas line from Carthage, Texas, to Middletown, Ohio. He may be addressed in care of that company, Steuck Bldg., Memphis, Tenn.

With the Mining Men

John R. Castano, who graduated from the College of the City of New York last June, is now a graduate assistant in geology at Northwestern University, Evanston, Ill.

John C. Chew graduated from Penn State last June with a B.S. degree in mineral economics and geology. Since then he has been working with the Phelps Dodge Copper Products Corp. as an engineer in a trainee capacity. The program is designed to acquaint the fledgling engineer with the various plants or those of most importance. He has worked at the wire and tube mill in the Bayway plant at Elizabeth, N. J., and at the Inca Mfg. division (enameling and insulation) at Fort Wayne, Ind. About the middle of January he expects to be transferred to the Habershaw division at Yonkers, N. Y., for the final phase of training.

George Bryan Coggins has been shifted to the Asheville, N. C., office of Bee Tree Vermiculite Mines, Inc. His mail goes to 201 Public Service Bldg.

In the first issues of the new magazines we are glad to tell members of the engagement of **Irene P. Klein** and **Ernest H. Sharp.** Wedding bells will ring Jan. 15. Members who visit Institute headquarters know Miss Klein as the friendly person who greets them as they step off the elevator, and who helps them with their problems, both professional and personal. Mr. Sharp, a Michigan College of Mines man, has worked in South America for the Anglo-Chilean Consolidated Nitrate Corp. and Cerro de Pasco, and in the States more recently with the Bureau of Mines, the FEA in Washington, and is now with Eagle-Picher in New York City.

Evan Bennett has moved to Chattanooga, Tenn., and resides at 4104 St. Elmo Ave.

Charles M. Brinckerhoff has been appointed general manager of the Chile Exploration Co. at Chuquicamata, Chile. **N. F. Koepel** takes over as general manager of the Andes Copper Mining Co. and the Potrerillos Railway Co. in Mr. Brinckerhoff's stead.

Edwin H. Crabtree, Jr., now of Eagle-Picher Mining and Smelting Co., First National Bank Bldg., Miami, Okla., has gone there from Tucson, Ariz.

William E. Crawford, former mill superintendent of Berens River Mines Ltd., is now addressed in care of the Quemont Mining Corp., Noranda, Que.

Forbes B. Cronk, general mining engineer for Oliver Iron Mining Co., receives his mail at 2416 East Third St., Duluth 5, Minn.

Robert J. Dalton is president and general manager of the Faire Mining Corp., 511 Baseline, San Bernardino, Calif.

James S. Dodge, Jr., wrote on Oct. 18 from his address, Natural Resources Section, GHQ, SCAP, APO 500, San Francisco, that he had made recently a field examination of the large Matsuo pyrite-sulphur mine in Iwate Prefecture. He had with him a copy of the August M&M and the article on the Greater Butte project was read avidly by the Japanese. He says that it is unfortunate that most of the Japanese mining industry is unable to obtain up-to-date American mining literature. Lack of a world monetary exchange rate prevents it.

J. Ward Downey has severed his connection with the Westvaco division of Food Machinery and Chemical Corp. For the past two years he has been mine superintendent at their property in Green River, Wyo., sinking a shaft and developing a large deposit of trona. His new address is Rm. 204, 1045 Sansome St., San Francisco, where he is engaged in consulting work, specializing in mine design and development.

Elmer R. Drevdahl, Jr., is working as a mining engineer on the engineering staff of the Inter-State Iron Co., Hibbing, Minn.

Joseph B. Elizondo has been acting as assistant geologist for the Cerro de Pasco Copper Corp., Cerro de Pasco, Peru, since his arrival in August.

R. H. S. Ewins, formerly with Lake George Mines, Captain's Flat, N.S.W., is now addressed Uruwira Minerals Ltd., Private Bag, Tabora, Tanganyika, Africa.

Norman R. Fisher, well-known mining specialist of Montreal, has been made chief consultant and mining engineer for the Greatlakes Copper Mines. He has prepared a report on drilling and the general operations at the property near Kashabowie in the Port Arthur mining division.

Victor G. Ford transferred from his job as manager of the Canutillos-Colavi section of the Bolivian Tin and Tungsten Mines Corp., to that of general manager of Cia. Minera y Agricola Oploca de Bolivia, Chocaya, on Sept. 1.

Frank W. Fruitman was honored recently by the British Government when he was named honorary officer of the military division of the Most Excellent Order of the British Empire. Colonel

Fruitman, whose address is 2919 E. 19th St., Tucson, Ariz., returned to the States last year from Germany, where he was in charge of mining and metallurgical operations in that country's western occupied zone. Before the war he was a mining and metallurgical engineer working in Arizona and California.

E. A. Gee has left College Park, Md., for Wilmington, Del., where he is a metallurgist in the pigments department of E. I. du Pont de Nemours & Co., Inc.

Paul W. Graff, president of Westmoreland Mining Co., Blairsville, Pa., will be receiving his degree in mining engineering this June from Pennsylvania State College.

Norman L. Grauerholz resides in Memphis, Nebr., where he is employed by the C. B. & Q. R. R. Co.

Stanley M. Moos

Stanley M. Moos has resigned as president and general manager of the Western Machinery Co., Mexico City, to establish a new company, Ponsford-Moos Equipment Co., 100 Texas St., El Paso, Texas. The aim of the company is to sell and service mining equipment in the southwestern United States, Mexico, and Central America.

Sydney E. Helprin is now a geologist in the Frick Laboratory, Roslyn, L. I., N. Y.

Howard R. Hendricks is doing special metallurgical research work for the Mt. Isa Mines Ltd., Mt. Isa, Queensland, Australia. He will be there for about one year as he is only on loan from the Shattuck Denn Mining Corp.

Arne Hofseth joined the staff of Aktieselskapet Sydvaranger as superintendent of their iron mines at Kirkenes, Norway, in November. He had been employed for thirteen years as a mining engineer by A. S. Sulitjelma Gruber.

A. Allan Bates

A. Allan Bates can be reached at the Portland Cement Association, 33 West Grand Ave., Chicago, Ill. He is vice-president of the Association.

Frederick C. Green has been promoted to assistant general manager of the Chino mines division of the Kennecott Copper Corp., at Hurley, N. Mex. He has been with Kennecott since 1939, serving as mill superintendent and general superintendent of Chino mines.

C. S. Gwynne, who had been teaching at Mayaguez, Puerto Rico, has returned to his home in Ames, Iowa, where he resumes his work at Iowa State College as associate professor of geology.

James Allen Haertlein, on returning from Maracaibo, Venezuela, where he was employed by the Creole Petroleum Co., has settled at 44 Marion Rd., Watertown 72, Mass.

Bernhard K. Haffner can be reached care of the American Embassy, The Hague, Netherlands. He is working with the ECA Mission to The Netherlands.

Dennis F. Haley now lives at 29 East 64th St., New York, N. Y.

W. A. Hardy returned on Oct. 28 to India to resume his duties as agent and general manager of the Central Provinces Manganese Ore Co., Nagpur, C. P., India. He had been in England.

J. S. Hazen has migrated from Holyoke, Mass., to Hamilton, Ill., P. O. Box 285.

Arthur S. Hecht, consulting mining engineer for the Department of Commerce, USAFIK, Korea, recently returned from Korea to the States. He is being retained by the Civil Affairs Division of the Army to act as consultant on technical matters concerning ore beneficiation tests now in progress in this country. At present he may be contacted at 342 27 Ave., San Francisco 21.

Warren L. Howes is with Western-Knapp Engineering Co., at 220 Power Bldg., Hibbing, Minn.

H. Herbert Hughes of the Studebaker Corp. is working for the ECA in Paris. He can best be reached now by addressing him Paris (ECA), care of Department of State Mail Rm., Washington 25, D. C.

Charles F. Joy, formerly with the International Smelting and Refining Co. as assistant geologist at the North Lily mine in Eureka, Utah, is now resident geologist at the Shoshone division of the Anaconda Copper Mining Co. in Tecopa, Calif.

M. R. Klepper, geologist for the USGS, receives his mail at 157 So. Howard St., Spokane 8, Wash.

James A. Knight, who was in Reno, Nev., is now at 231 East Sixth St., Hinsdale, Ill.

F. Clyde Lendrum is now mill superintendent for Anacon Lead Mines Ltd., Montauban Les Mines, Portneuf County, Que. He was formerly with Normetal Mines Corp.

Charles A. Lindsay is production manager for the Los Angeles division of Stauffer Chemical Co. His residence is 533 Via Media, Palos Verdes Estates, Calif.

Jimmie A. Littrell, a student at the University of Arizona, lives at 53-A Polo Village, Tucson, Ariz.

Victor M. Lopez is with the Organizacion Internacional de Investigaciones, Industriales de Venezuela, Caracas, Venezuela.

Anthony M. Mastrovich, formerly with the U. S. Vanadium Corp. at Uravan, Colo., as engineer and geologist, is exploration engineer in the western mining department of the American Smelting and Refining Co., Pacific National Life Bldg., Salt Lake City.

George E. McCormack, who has been at the Missouri School of Mines, is now working in the engineering department of the Hatfield-Campbell Creek Coal Co., Rensford, W. Va.

C. E. Miller has assumed the post of chief mining engineer with his present employers, Chrestien Mica Industries, Ltd., Domchanch P. O., Via Kodarma E. I. Rly., Behar, India.

Maurice A. Moore has moved from Kalgoorlie, W. Australia, to Ferry Rd., Southport, Queensland, Australia. He is with Associated Minerals Pty. Ltd.

Adolph E. Parr has left sunny Cali-

fornia for Nome, Alaska. His box number is 438.

Nels P. Peterson has left University Station, Tucson, Ariz., and is no longer available for consulting work. His new address is Box 1211, Globe, Ariz.

George W. Roddewig, consultant to the American Zinc, Lead and Smelting Co., may now be addressed at 108 S. Glenroy Ave., Los Angeles 24.

Adolph E. Sandberg is professor of geology at Lousiana State University, Baton Rouge, La.

J. Watts Scott is supervisor of mineral leases for the Tennessee Coal, Iron and Railroad Co. His mail will reach him at Rt. 1, Box 43, Jemison, Ala.

Joe W. Stewart, whose residence is 810 N. W. 41st Ave., Miami, Fla., is hydraulics engineer for the USGS.

Charles G. Tebelman, Jr., is employed by the Bethlehem Steel Co., 700 E. Third, Bethlehem, Pa.

Wilber D. Walker resides at 213 So. 9th Court, Bessemer, Ala., and is acting as industrial engineer for the Tennessee Coal, Iron and Railroad Co.

Louis Ware, president of the International Minerals and Chemical Corp., has been elected a director of the Illinois Central Railroad Co. Mr. Ware has worked in Arizona, Chile, New York, and Chicago with several well-known companies and has been with International Minerals since 1939.

Judson H. Whitman has moved south from Ketchikan, Alaska, to work in the engineering department of Pend Oreille Mines and Metals Co., Metaline Falls, Wash.

John Weldon Wilson is agent for Shell Oil Co., Las Vegas, Nev. His mail should go to P. O. Box 350 there.

Bernard York is now engaged as assistant professor of mining at the University of California, Berkeley 4, Calif.

• In the Metals Divisions

John S. Absalom is attending the Missouri School of Mines and makes his residence at 1804 Oak St., Rolla, Mo.

Karl Anson Allebach is employed as a supervisor for North American Aviation, Inc., and commutes to work from his residence at 306 Georgina Ave., Santa Monica, Calif.

William J. Bannister is manager for the Wire Mills Products Division of British Insulated Callender's Cables Ltd., Prescot, Lancashire, England.

William H. Bassett, Jr., Lieutenant Colonel in the United States Army, has trekked south from Scarsdale, N. Y., to Birmingham, Ala. His mail should be sent in care of Birmingham Ordnance Division, 734 Frank Nelson Bldg.

William Raymond Bay, Jr., is employed by Irvington Smelting and Refining Works at Irvington 11, N. J.

Thomas E. Miller, after completing his studies at the University of Kansas, joined the Oklahoma Steel Castings Co., in Tulsa.

J. B. Carlock is now chief consulting engineer for the Loftus Engineering Corp., 610 Smithfield St., Pittsburgh 22.

R. Allen Crosby is a metallurgist for Carnegie-Illinois Steel Corp. and lives at 2120 East 73rd St., Chicago 49, Ill.

George M. Gordon, chief chemist, U. S. Naval Dry Docks, Hunters Point, San Francisco, is in residence at 15 Stephens Way, Berkeley 5, Calif.

Harry P. Croft

Harry P. Croft, former director of technical control and research for Chase Brass and Copper Co.'s Midwestern division, has been named vice-president in charge of development of the Wheeling Bronze Casting Co., Moundsville and Wheeling, W. Va. He had been associated with Chase Brass in various capacities, including chief metallurgist, for 26 years. Dr. Croft, a graduate of Rensselaer Polytechnic Institute, received his Ph.D. degree in metallurgy from Case Institute of Technology in 1942.

Robert T. Howard has resigned from his job with the Los Alamos Scientific Laboratory and has joined Black, Sivalls & Gryson, Inc., 7500 E. 12th, Kansas City, Mo., where he will be associated with the quality control director.

Hjalmar W. Johnson

Hjalmar W. Johnson was recently named vice-president in charge of steel manufacturing for the Inland Steel Co. Mr. Johnson went to Inland in 1929 as assistant superintendent of blast furnaces. In 1930 he was promoted to superintendent of blast furnaces. He was made assistant general superintendent of the Company's Indiana harbor works in 1942 and remained there until 1946 when he was appointed staff assistant to the president.

Clarence B. Randall has been named assistant to the president of the Inland Steel Co. He had been vice-president in charge of raw materials since 1930. Well-known in the steel industry, Mr. Randall came to Inland Steel in August, 1925, as assistant vice-president. A graduate of Harvard University, he had previously practiced law in Ishpeming, Mich.

Wilfred Sykes' term of office as Inland Steel Co. president was recently extended by the board of directors beyond his normal retirement date of Dec. 31, 1948. He will continue his services thereafter in such capacity and for such period of time as the directors may subsequently determine.

Carl S. Wiedman is research metallurgist for the Carboloy Co., Detroit. His address is 5281 Beaconsfield, Detroit 24, Mich.

• In Petroleum Circles

Ray W. Amstutz is a petroleum engineer for Earlougher Engineering and can be reached at 319 E. 4th, Tulsa.

Edward I. Barton, junior geophysicist for Gulf Research and Development Co., receives his mail at Box 1096, Shawnee, Okla.

Frank W. Abrams

Frank W. Abrams, chairman of the board of the Standard Oil Co. of N. J., has been made national chairman of the forthcoming $15,000,000 Syracuse University building and development fund. Mr. Abrams received his civil engineering degree from the College of Applied Science at Syracuse in 1912 and an honorary LL.D. degree from the University in 1946.

E. M. Benson, Jr., petroleum engineer for the Richfield Oil Corp., may now be addressed at Box 147, Bakersfield, Calif.

Byron B. Boatright is now vice-president of the Conroe Drilling Co. with an office in the Brown Bldg., Austin, Texas.

Don R. Bowcutt, formerly of Butte, is an engineering clerk for Phillips Petroleum Co., Cut Bank, Mont.

Stuart G. Branyan, district engineer for the Carter Oil Co., receives his mail at Magnolia, Ark.

Chester U. Burk has left Texas for Oklahoma City. His mail goes care of Kobe Inc., Box 4515, S. E. 29th St., Oklahoma City.

Robert A. Cadigan is working for the USGS on the Colorado plateau project at Grand Junction, Colo.

George R. Chenot is now geologist for the Standard Oil Co. of Texas, at Dallas.

Wallace H. Collins is now with Shell Oil Co., Inc., Box 1191, Tulsa.

Maurice Deul has a job in the section of geochemistry and petrology of the U. S. Geological Survey, Washington 25, D. C.

Norman S. Domenico, after graduation from the Colorado School of Mines last spring, worked as a computer on a seismograph crew of the Atlantic Refining Co. in Wyoming. This fall he enrolled as a graduate assistant in the geological sciences division of the California Institute of Technology and is now studying toward an advanced degree. His address is 1126 Cordova, Pasadena 5, Calif.

Jules A. Durand is inspector of mines in Seine et Oise Province, France.

Wesley G. Gatlin is training as a petroleum engineer for The Texas Co. at Houma, La.

Jerry V. George is temporarily at A & M College of Texas but receives his mail at Rt. 1, Milford, Texas.

Walter F. Gerhard, with Amerada, may now be addressed at P.O. Box 103, Los Alamos, Calif.

Lee W. Gibson, consulting geological engineer, makes his office at 616 Indianapolis, Huntington Beach, Calif.

James L. Minahan

James L. Minahan, geologist for the USGS, receives his mail at Box 590, Thermopolis, Wyo.

Edward H. Griswold, petroleum engineer, has moved from Midland, Texas, to Pebble Beach, Calif.

Ellis W. Hamilton is doing production and drilling work for Kern Oil Co., Ltd., at Bakersfield, Calif.

John L. Hoyt, Jr., is assistant general superintendent for Pan American Production Co., Meilie Esperson Bldg., Houston, Texas.

Clarence B. Hussey, formerly with Gulf at Kermit, Texas, has been transferred to Odessa, Texas, where he is zone petroleum engineer for the Gulf Oil Corp.

Julian E. Huzarevich, recently of Fort Worth, is now a junior petroleum engineer for Stanolind Oil and Gas Co., Tulsa.

David J. Kull is an exploration trainee with Shell Oil Co. at Houston.

Robert M. Leibrock has moved from Arkansas to 619 N. Osage Dr., Tulsa.

W. T. Mendell is now working for himself. He will be doing consulting petroleum geology and engineering; his office is 1902 Second National Bank Bldg., Houston, Texas.

Gregor C. Merrill is Paris representative for United Overseas Petroleum Co., Ltd. His mail should be sent to 7 Place Vendome, Paris 1.

Harold L. Moseley is a petroleum engineer for D & W Oil Tool Co., Inc. He should be addressed Box 1215, Corpus Christi, Texas.

L. Murray Neumann, formerly consulting geologist with the Carter Oil Co. of Tulsa, has opened an office at 412 Palace Bldg., Tulsa.

Basil V. Savoy, who was with Central Pipe Line Co., is now a petroleum engineer for Continental Oil Co., Houston, Texas.

Ralph J. Schilthuis, assistant superintendent of the gas division for Humble Oil and 1939 Alfred Noble Prize winner, resides at 3747 Purdue, Houston.

Raymond D. Sloan has been shifted by the Carter Oil Co. from Billings, Mont., to Denver.

Dallas R. Staples, field engineer with The Texas Co., gets mail at Box 1, Premont, Texas.

Karl R. Tripp, a trainee of The Texas Co., has been moved to Pampa, Texas.

Owen M. Watkins, Jr., is now junior production engineer for the Pan American Production Co., 108½ Chaparrel, Corpus Christi, Texas.

F. Raymond Wheeler, of Chemical and Geological Laboratories Inc., has migrated from Tulsa to the Casper, Wyo., office.

Obituaries

Harold S. Munroe

A Tribute by Wilbur Judson

THE many friends of Harold S. Munroe ("Jack") were deeply grieved to hear of his passing away in Miami, Fla., on Oct. 15. He had had several heart attacks during the past few years but had recovered from all of them, so he was fairly active and, while not being able to take too much responsibility, was enjoying good health and comfort. His sudden death is therefore a special shock.

Munroe had a wonderful personality, making friends easily and keeping them.

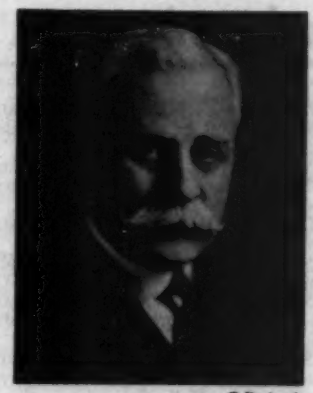
His sense of humor was delightful and it was a pleasure to be in his company. Few mining engineers have had the wide friendships he enjoyed, both in the United States and abroad, especially in England. He also had many close friends among the hard-rock miners in different parts of the world. Everyone liked him—a great tribute to any man.

I first met Munroe in Panama in 1906. Both of us were on our way to take jobs in a copper mine, in the Argentine, which closed down the following year in the depression of 1907. After that we were together in Mexico most of the time—in fact, until Munroe left there around 1913. Since that time it was my pleasure to see him fairly often, so we renewed our old friendship as often as possible.

After leaving Mexico he, in turn, was general manager of the Consolidated Coppermines in Nevada; vice-president and general manager of the Granby Consolidated Mining, Smelting and Power Co., with headquarters at Anyox, B. C.; mining engineer for The American Metal Co.; and mining engineer with the Newmont Mining Corp. Through Newmont he was employed as consulting engineer for the Rhokana Corp., owning and operating copper mines in Rhodesia. In his capacity as general manager of the Rhokana operations, he had the responsibility for equipping and operating the mine, mill, and smelter at the N'Kana mine in Northern Rhodesia—one of the largest copper mines of the world. In 1935 he returned to North America and became director and consulting engineer for Ventures, Ltd., living in Toronto. I believe it is correct to say that he was one of the great mine operators of his generation, having a flair for building and handling an organization such as few men possess.

While in Toronto he had his first heart attack, incapacitating him for continuous strenuous effort. After leaving Toronto he moved to Fort Lauderdale, Fla., and a little over a year ago he moved to Tryon, N. C. Munroe's scholastic training was at Cornell and the Colorado School of Mines. He will be missed by his many friends for whom a visit with him was a most pleasant event and happy memory.

RANDOLPH SIMPSON (Member 1940), chief metallurgist for the Electric Steel Foundry Co., died recently at his home in Portland, Oreg. A native of Massachusetts—born there 62 years ago—he migrated to Portland in 1912, soon after receiving a B.S. from Dartmouth College. In that city he did chemical work for the Santa Cruz Portland Cement Co. and the Portland Gas and Coke Co., before he went to Electric Steel. This last professional association was made in 1920.



Bachrach

John Allen Coe

JOHN ALLEN COE (Member 1923), who retired recently after spending sixty years in the brass business, passed away Aug. 4, shortly before his eightieth birthday. Mr. Coe was introduced to that business through the Birmingham Brass Co., with whom he spent the first nine years of his career. When he left it, he joined the American Brass Co., in Waterbury, Conn., as a sales manager. But soon he was advanced, successively, to the positions of assistant to the president, vice-president, and president. Although he "retired" in 1945, he retained a connection with the Company, as a director.

FREDERICK GARDNER COTTRELL (Member 1912), a humanitarian who expressed his benevolence for society as a chemist, metallurgist, and inventor, died Nov. 16, while attending a business meeting of the National Academy of Sciences, at the University of California, in Berkeley. His death concluded 71 years of trying to further the comfort and well-being of humanity. And he was successful in his efforts, mainly through the Research Corp.

Dr. Cottrell established this nonprofit organization in 1912, in order to make his electrical precipitator available to everybody; he rejected the opportunity to take for himself the profits from his invention. In the years that followed, Dr. Cottrell saw that the Research Corp.'s profits went back into more research, in colleges and scientific institutions. To date, the organization has provided approximately $3,500,000 for scientific research, and the bulk of that sum has come from Dr. Cottrell's invention.

He perfected the electrical precipitator that bears his name between 1906 and 1909, while an assistant professor of chemistry at the University of California, his first *alma mater*. The other two schools he attended are the University of Berlin, where he earned an M.A. degree, and the University of Leipzig, where he earned a Ph.D.

When he left his teaching work, Dr. Cottrell joined the Bureau of Mines as a consulting chemist. From this position he was appointed, consecutively, chief physical chemist, chief chemist, chief metallurgist, assistant director, and director. During the time he was with the Bureau he developed a process for manufacturing helium gas at a cost that made it practical for popular use. He also did considerable work in the metallurgical field toward developing equipment for preheating air used in metallurgical operations.

Among his many other accomplishments was the formation of Research Associates, also a nonprofit organization. Through it, Dr. Cottrell conducted scientific and social research, attempting to eliminate, as far as possible, the time lag between the perfection of scientific ideas and their introduction into national life.

MYRIL L. JACOBS, vice-president of Bethlehem Steel Co.'s raw material properties, died Nov. 13 at the Pan American guest house, Trinidad, B. W. I., of a circulatory failure. He had been taken ill the previous evening at Bethlehem's Palua mine and flown to the Piarco airport.

Mr. Jacobs was born May 16, 1885, at Weldbank, Pa. He received his early education in the schools of the community and at Marietta College and Mercersburg Academy. In 1910 he was graduated from Lehigh with a degree in mining engineering.

He began his business career as assistant engineer for Astoria Light, Heat and Power Co. that same year. In 1912 he was employed by the Mexican Light and Power Co. as assistant engineer in charge of hydroelectric tunnels and dams. The following year he accepted a position as assistant engineer with the New York Municipal Railways in Brooklyn. In 1916 he became engineer for F. H. Clement & Co. at Bethlehem, Pa., and continued in this position until 1920.

At that time he was made general manager of quarries, for Bethlehem Steel Co., in 1934 general manager of the stone and slag division, and in 1939 assistant to the vice-president. The next year Mr. Jacobs was appointed vice-president of Bethlehem Steel Co. and president of various Bethlehem subsidiary companies engaged in mining. He was elected a director of Bethlehem Steel Corp. on Jan. 25, 1940.

EDWARD BEISEL SNYDER (Member 1926), a mining engineer who devoted his entire professional career to service with the Hazle Brook Coal Co., died on April 25, at the age of 57. Mr. Snyder first worked about the Hazle

Necrology

Date Elected	Name	Date of Death
1923	John Allen Coe	Aug. 4, 1948
1912	Frederick G. Cottrell	Nov. 16, 1948
1907	William H. Emmons	Nov. 5, 1948
1934	H. Clarence Horwood	Oct. 30, 1948
1917	Myril L. Jacobs	Nov. 13, 1948
1913	Harold S. Munroe	Oct. 15, 1948
1940	Randolph Simpson	Unknown
1926	Edward B. Snyder	April 25, 1948

Brook anthracite mines, in Pennsylvania, during his summer vacations, while a student at Lehigh. After graduation in 1914, with the degree of E.M., he started his career with the Company on a full-time basis. However, three years later, World War I intervened, and he joined the U. S. Army Artillery as a Private. When he was discharged from service in 1919, as a Second Lieutenant, he returned to Hazle Brook, and there remained until his recent death.

Proposed for Membership

Total AIME membership on November 30, 1948, was 15,433; in addition 3687 Student Associates were enrolled.

ADMISSIONS COMMITTEE

Albert J. Phillips, Chairman; James L. Head, Vice-Chairman; George B. Corless, T. B. Counselman, George C. Heikes, W. B. Plank, P. D. Wilson, E. M. Wise.

Institute members are urged to review this list as soon as the issue is received and immediately to wire the Secretary's office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified.

In the following list C/S means change of status: R, reinstatement; M, member; J, Junior Member; A, Associate; S, Student Associate; F, Junior Foreign Affiliate.

ALABAMA

Adamsville — MARSHALL, CLARENCE GANES. (M). Electrical engineer, coal mines, Tennessee Coal, Iron and Railroad Co.

ARIZONA

Humboldt — ZINKL, ANDREW JOSEPH. (R,C/S—S-M). Assistant superintendent, Iron King branch, Shattuck Denn Mining Corp.

CALIFORNIA

Alhambra—ELSON, WILLIAM HAROLD, JR. (R,C/S—S-J). Petroleum engineer, Shell Oil Co. GARDNER, JOHN WILLIS. (R,C/S—S-M). Field engineer, Gardner-Denver Co.

Bakersfield — CHARLES, WILLIAM WATHEN, JR. (C/S—J-M). Geologist, Pacific Western Oil Corp. WELLER, ARTHUR REILLY. (J). Junior exploitation engineer, Shell Oil Co.

Berkeley—PASK, JOSEPH A. (M). Associate professor of ceramic engineering, division of mineral technology, University of California (Berkeley).

Grass Valley—KREBS, RICHARD WILLIAM. (M). Mill superintendent, Idaho Maryland Mines Corp.

Hammonton—PRATT, MORTON EDISON, JR. (C/S—S-J). Research engineer, Yuba Cons. Gold Fields.

Hollywood — PENN, CHARLES JAMES. (M). Editor, *Petroleum Register*.

Keeler — MACKEVETT, EDWARD MALCOLM, JR. (C/S—S-J). Junior geologist, minerals section, U. S. Geological Survey.

Los Angeles—MACLEAN, NORMAN EWEN. (M). Southwestern sales manager, American manganese steel division, American Brake Shoe Co. NATCHER, STANLUS Z. (M). Assistant to the vice-president of conservation, Standard Oil Co. of California. PEARSON, GERALD THOMAS. (C/S—J-M). General production superintendent, Continental Oil Co. WERNER, SCOTT JOHN. (J). Petroleum engineer, Socony Vacuum Oil Co.

Placentia—MCNEILL, JAMES MICHAEL. (M). Assistant to vice-president, Union Oil Co. of California.

San Francisco—UTT, RALPH BERNARD. (M). General sales manager, Western Machinery Co. WYNER, ALEXANDER S. (R, C/S—JA-M). Mining engineer, Pittsburgh Testing Laboratory.

San Jose—JACK, ORVILLE E. (M). Chief chemist, Permanente Cement Co.

Saratoga—PRONCER, NORMAN WILLIAM, JR. (C/S—S-J). Miner, Sunshine Mining Co.

South Gate—ALEXANDER, JAMES FREDERICK. (J). Division engineer, California division, Lane-Wells Co.

COLORADO

Denver—GARDNER, EVERETT MATTHEWS. (M). District manager, Sheffield Steel Corp.

CONNECTICUT

Kensington — SPENCER, LESTER FUOC. (M). Chief metallurgist, Landers Frary & Clark.

New Haven—FLAWN, PETER TYRELL. (J). Geologist, P-1, U. S. Geological Survey.

FLORIDA

Bartow—BECKER, JOHN NATHAN. (J). Mining superintendent, Virginia-Carolina Chemical Corp. SHERERTZ, JOE RAYMOND. (M). Chemical engineer, Davison Chemical Corp.

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Mulberry—CLARK, RAYMOND HAROLD. (M). President, R. H. Clark Equipment Co.

IDAHO

Patterson—ANDERSON, JOHN SANFORD. (C/S—J-M). Mill superintendent, Ima mine, Bradley Mining Co.

ILLINOIS

Chicago — NICHOLSON, MORRIS EMMONS, JR. (C/S—S-M). Research metallurgist, Standard Oil Co. (Indiana). WATSON, RAYMOND EDWARD. (J). Assistant petroleum engineer, Standard Oil Co. (Indiana).

Flossmoor—EISAMAN, JACK H. (M). Superintendent, No. 2 electric furnaces, Carnegie-Illinois Steel Corp.

Waukegan—PREST, J. IRVING. (M). Metallurgist, Johnson motors division, Outboard Marine and Mfg. Co.

INDIANA

Evansville — SAMUEL, DAVID GRIFFITH, JR. (R,C/S—J-M). Sales engineer, Hannischfeger Corp.

Wabash—ECKES, LEROY JOHN. (J). Research analyst, American Rock Wool Corp.

KANSAS

Independence — MACIVOR, RODERICK KEN. (J). Water flood engineer, Sohio Petroleum Co.

Ulysses—WAGNER, ROBERT JAMES. (J). Junior petroleum engineer, Stanolind Oil and Gas Co.

KENTUCKY

Madisonville — MCCLOSKEY, JOHN ROBERT. (R,C/S—J-M). Sales-service engineer, Hercules Powder Co.

LOUISIANA

Benton—MILLS, EARNEST JEROME. (M). Project superintendent, Barnsdall Oil Co.

Lafayette — PARKER, JOSEPH BRIGHT. (J). Junior petroleum engineer, Stanolind Oil and Gas Co.

MICHIGAN

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MINNESOTA

Biwabik—BAKER, ROBERT ALLEN. (C/S—S-J). Mining engineer, Pickands Mather & Co.

Duluth—FERRIS, JOHN A. (C/S—J-M). Mechanical engineer, Oliver Iron Mining Co.

Hibbing — GLEASON, MICHAEL, JOHN. (M). Diamond drilling superintendent, E. J. Longyear Co.

MISSISSIPPI

Bonne Terre—JEWELL, JAMES EDWIN. (R,C/S—JA-M). Geologist, St. Joseph Lead Co.

West Jackson — HERRALD, ARTHUR EASTON. (M). Division engineer, Schlumberger Well Surveying Corp.

MISSOURI

St. Louis—DESLOGE, JOSEPH JOHN. (J). Student, Washington University. HEWITT, LOWELL CLELAND. (M). Vice-president and director of research, Laclede Christy Co. LYNOTT, WILLIAM JOHN. R,C/S—S-M). Instructor, geology department, Institute of Geophysical Technology, St. Louis University.

NEW JERSEY

Morristown—ACKERMAN, DAVID HARTON. (J). Geological assistant, Jones & Laughlin Steel Corp.

Plainfield — GERWIN, BENJAMIN HARRISON. (A). Supervisor of refining operations, Kennecott Copper Corp.

Rahway — LEICH, GILBERT MERLIN. (M). Research engineer, Metal and Thermit Corp.

NEW MEXICO

Carlsbad—MILLS, RUSSELL HOLBROOK. (M). Refinery superintendent, U. S. Potash Co.

Hanover—HUYETT, STERLING SUTPHEN. (R,C/S—J-M). Mine chief, Empire Zinc Co.

NEW YORK

Brooklyn — KORMAN, SAMUEL. (M). Metallurgical chemist, Phelps Dodge Corp.

Larchmont — DEAN, ROBERT GRIFFIN.

(C/S—S-J). Junior engineer, Alcoa Mining Co.

Lyon Mountain—ZIMMER, PAUL WILLIAM. (C/S—J-M). Geologist, Republic Steel Corp.

New York—ILIOPOULOS, GEORGE. (A). Vice-president, Silver and Barytes Ores Mining Co. PAPPAS, HERCULES CRIS. (C/S—S-J). Junior engineer, Alcoa Mining Co.

Scotia—GAUS, JOHN ERNEST. (C/S—S-J). Metallurgist, scientific program, General Electric Co.

Tahawus—ROGERS, JAMES JOHN, JR. (J). Geologist, titanium division, National Lead Co.

OHIO

Columbus—ELSNER, FRANCIS ROBERT. (J). Research engineer, Battelle Memorial Institute.

Shaker Heights—FOLK, JOHN KENNETH. (J). Laboratory metallurgist, American Steel and Wire Co.

OKLAHOMA

Ardmore—MILLARD, FRANK STUTZMAN. (R,C/S—J-M). Chief engineer and district manager, Schlumberger Well Surveying Corp.

Blackwell — PAGE, HERBERT ROBERT. (M). Assistant superintendent, Blackwell Zinc Co.

Picher—STOVER, CURTIS EDWARD. (R—M). Secretary, Tri-State Zinc and Lead Ore Producers Assn.

Tulsa—LEWIS, MAURICE, JR. (C/S—S-J). Junior exploitation engineer, Shell Oil Co. STOCKER, STANLEY HARRISON. (J). Petroleum engineer, Stanolind Oil and Gas Co. WHITE, FOSTER LEE. (M). Captain, design and development officer, U. S. Air Force.

OREGON

Eugene — BALDWIN, EWART MERLIN. (C/S—J-M). Assistant professor of geology, University of Oregon.

Portland—JACOBS, CHARLES W. F. (J). Ceramist, department of geology and mineral industries, State of Oregon. MATTHEWS, THOMAS CHARLES. (M). Spectroscopist, department of geology and mineral industries, State of Oregon. MILLER, ROY EDMUND. (M). President and general manager, Miller Products Co.

PENNSYLVANIA

Bethlehem—AYLWARD, PAUL THOMAS. (J). Research engineer, Bethlehem Steel Co. DENNISON, JOSEPH DONAHEY, JR. (J). Research engineer, Bethlehem Steel Co.

Greensburg—REYNOLDS, REXFORD VINCENT. (M). Development engineer, Kennametal, Inc.

Lehighton—HANDWERK, GLENN ERWIN. (J). Student engineer, Gulf Refining Co.

Pittsburgh—FLOYD, WALTER INGRAM. (A). President, Duff-Norton Co. GOLDMAN, KENNETH MARVIN. (J). Research assistant, Carnegie Institute of Technology. GULBRANSEN, EARL ALFRED. (M). Advisory engineer, Westinghouse Research Laboratories. ROWLAND, DUDLEY HAMILTON. (M). Research associate, Carnegie-Illinois Steel Corp.

TENNESSEE

Chattanooga — RIVERS, CURTIS FRED. (M). General superintendent of coal mines, Tennessee Products and Chemical Corp.

Oak Ridge—WILLIAMS, ROBIN O'DARE. (J). Junior metallurgist, Oak Ridge National Laboratory.

Whitwell — DAFFRON, HERSCHEL ANDREW. (M). Mine superintendent, Tennessee Products and Chemical Corp.

TEXAS

Agua Dulce—GIRAND, CHARLES FRANCIS. (R,C/S—S-M). Petroleum engineer and field superintendent, Rand Morgan.

Alice — WILSON, GEORGE STANWOOD. (M). District petroleum engineer, Magnolia Petroleum Co.

Andrews—SULLIVAN, RICHARD JOSEPH. (C/S—S-J). Petroleum engineer, Stanolind Oil and Gas Co.

Bellaire — ROBISHAW, EARL JOSEPH. (M). Research engineer, A-1 Bit and Tool Co.

Bishop — MAY, JONATHAN THOMAS. (M). District superintendent, Chicago Corp.

College Station—PERSONS, JOHN VERNER. (R,C/S—S-M). Assistant professor, Agricultural and Mechanical College of Texas.

Corpus Christi—BRUMBY, BIRTO RALSTON. (R,C/S—S-M). Production superintendent, Panhandle Production and Refining Co. CLARK, JAMES MUIR. (M). Assistant superintendent, production and drilling, Chicago Corp. JOHNSON, FRANK AUBREY. (M). Division superintendent, Halliburton Oil Well Cementing Co.

Dallas—BIXLER, WILLIAM ROYCE. (J). Petroleum engineer, Atlantic Refining Co. TENNANT, ROBERT HUDSON. (J). Petroleum geologist, De Golyer & MacNaughton. WALKE, JOHN EDWIN. (M). Gas engineer, Sun Oil Co.

Houston — BEATTY, ROBERT MACCONNELL. (M). Geologist, Trinity Petroleum Co. BLEAKLEY, WILLIAM BRUCE. (C/S—S-J). Junior petroleum engineer, Stanolind Oil and Gas Co. GOLDEN, ALBERT COURTER. (M). Assistant to the vice-president, Pan American Production Co. JOHNSON, ROBB C. (J). Engineer, Houston Oil Field Material Co. MAIN, THOMAS COLE. (R,C/S—S-M). Chief process design engineer, Cons. Western Constructors, Inc. WILSON, ERNEST BRADLEY, (M). Engineer and geologist, Sterling Oil and Refining Corp.

Levelland—MCSPADDEN, THOMAS WILLARD. (C/S—J-M). Head roustabout, Stanolind Oil and Gas Co.

Midland — FARIS, CHARLES WILLIAM. (M). Partner, Faris & Warren.

Odessa—HARDEE, PECK, JR. (R,C/S—S-J). District engineer, Texas Pacific Coal and Oil Co. HENLEY, JACK. (J). District geologist, Lane-Wells Co.

Overton—THOMPSON, FREDERICK LUTHER, JR. (C/S—J-M). Petroleum engineer, Humble Oil and Refining Co.

Pittsburg—KENT, LEON ALFRED. (J). Engineer-draftsman, Lone Star Steel Co.

Victoria—BINKLEY, JOHN FREDERICK. (R,C/S — S-M). Petroleum engineer, Barnsdall Oil Co.

UTAH

Salt Lake City—WHITE, JOHN BLACKWOOD, JR. (C/S—J-M). Field engineer, Galigher Co.

WASHINGTON

Bellingham — PASCOE, JAMES HENRY. (M). Vice-president and general superintendent, Bellingham Coal Mines, Inc.

Metaline — SEERLEY, JOHN JOSEPH. (C/S—S-J). Mine shift boss, Pend Orielle Mines and Metals Co.

Olympia—STANTON, WILLIAM LAYTON. (M). Division geologist, Union Oil Co. of California.

SEATTLE—DONG, JAMES Y. (C/S—S-J). Chemist, Bethlehem Pacific Coast Steel Co.

WEST VIRGINIA

Fairmont—KINCERY, DONALD SAMUEL. (R,C/S—J-M). Senior mining engineer, Bureau of Mines.

Fayetteville — LONG, JOHN BROADUS. (M). President, Long Super Mine Car Co.

WYOMING

Laramie — PAINE, WILLIAM RHODES. (C/S—S-J). Graduate school student, University of Wyoming.

ALASKA

Fairbanks—PROEHL, NORMAN PRESTON. (C/S—J-M). Mining engineer, U. S. Smelting Refining and Mining Co.

ONTARIO

West Lorne—EVANS, JOHN ROY. (C/S—S-J). Trainee, Creole Petroleum Corp.

QUEBEC

Montreal — ROBERTSON, ALEXANDER HUGH. (M). Vice-president, Quebec Iron and Titanium Corp.

CHILE

Chuquicamata—THURSTON, FRANK EDWARD. (M). Junior engineer, Chile Exploration Co.

PERU

Cerro de Pasco — SHELTON, DEREK CLIFTON. (C/S—S-J). Assistant mine foreman, Cerro de Pasco Copper Corp.

ENGLAND

Birmingham — SWINDELLS, NORMAN. (R,C/S—F-M). Chief metallurgist, McKechnie Bros., Ltd.

Warwickshire — CROWTHER, JAMES. (M). Research metallurgist, James Booth & Co.

FRANCE

Mont-Saint-Martin — GUINARD, PIERRE AIMÉ. (M). Director of mines, Société des Aciéries de Longwy.

GREECE

Laurium — CONOFAGOS, CONSTANTIN. (M). Chief metallurgist, Cie. Française des Mines de Laurium.

TANGANYIKA

Tabora — LANDCASTLE, RALPH. (M). Inspector of mines, Government of Tanganyika.

CHINA

Hopeh—LU, TING-TSEH. (C/S—S-J). Training student, Kailan Mining Adm. WANG, TSU-NA. (C/S—S-J). Training student, Kailan Mining Adm.

Peiping—HU, KAO CHIANG. (C/S—S-J). Research fellow, national bureau of mining and metallurgical research, Ministry of Economic Affairs.

VICTORIA

Melbourne—BARTH, HANS FRIEDRICH WILHELM. (M). Metallurgist, C. Huppery & Co.

Student Associates

Elected December 15, 1948

Robert K. Aaker.....Univ. N. Dak.
John J. Abendschan...Colo. Sch. Mines
James L. Albright..Texas Mines & Met.
Howard A. Anderson, Jr.
Colo. Sch. Mines
Donald I. Andrews.....Colo. Sch. Mines
Charles H. Armitage.....Univ. Wis.
Donald G. Ashe.....Colo. Sch. Mines
Herbert J. Ashe (Rein.)
Colo. Sch. Mines
Henry E. Aviles.....Univ. Ariz.
Robert L. Ballard.....Ohio State
John G. Barnes.....Univ. N. Dak.
Virgil D. Basinger.....Ohio State
John H. Bassarear.....Colo. Sch. Mines
James R. Bassett.....Yale Univ.
Kenneth M. Bearden..Texas Mines & Met.
William L. Beaton, Jr.
Texas Mines & Met.
Thomas E. Benedict.....Okla. A&M
Jack B. Bennett.....Colo. Sch. Mines
Roshan B. Bhappu.....Colo. Sch. Mines
Irfan N. Bilen.....Ohio State
James C. Birtell.....Okla. A&M
Benson D. Blackie.....Ohio State
Wayne F. Bohanan.....Colo. Sch. Mines
Leo Borasio.....Colo. Sch. Mines
Robert E. Bosco.....Colo. Sch. Mines
Charles D. Bowling.....W. Va. Univ.
Quinn G. Boyd.....Texas Mines & Met.
Leo N. Bradley.....Colo. Sch. Mines
Robert J. Brakey, Jr.....Okla. A&M
John A. Brandon.....Colo. Sch. Mines
James E. Brazell.....Okla. A&M
Robert E. Brooks.....Univ. Okla.
Robert L. Brown.....Univ. Ill.
Robert A. Burney.....Ohio State
Robert L. Burns.....S. Dak. Sch. Mines
Dewey J. Bushaw.....Univ. N. Dak.
Daniel W. Butner, Jr. .Colo. Sch. Mines
Franklin W. Butterfield.....Univ. Nev.
Tom G. Calhoun.....Texas A&M
Samuel H. Caran.....Ohio State
Melvin Carlson.....Colo. Sch. Mines
Arduino Castrale....Mo. Mines & Met.
Clifford H. Chandler.....Ohio State
Wei K. Chang.....Mo. Mines & Met.
Donald D. Christofferson..Univ. N. Dak.
Robert K. Christofferson....Okla. A&M
Donald G. Christy.....Univ. N. Dak.
Richard J. Clifford.....Ohio State
Robert K. Collins....S. Dak. Sch. Mines
Dowd L. Cooper.....Oreg. State Coll.
Earl J. Cox.....S. Dak. Sch. Mines
Bob C. Crittendon.....Okla. A&M
William C. Cross...Texas Mines & Met.
John T. Cullom.....Mo. Mines & Met.
Donald A. Damkroger.....Univ. Nev.
Wesley F. Danielson.....Univ. Minn.
Raymond E. Daugherty
Mo. Mines & Met.
William D. DeGeer, Jr.....Univ. Okla.
Karl H. DelPorte.....Mo. Mines & Met.
Charles F. Deuel.....Colo. Sch. Mines
Tony J. DiPrimo.....Mo. Mines & Met.
Russell P. DiSano.....Queens Univ.
Billy F. Dittman.....Colo. Sch. Mines
Danford J. Dodds.....Colo. Sch. Mines
Jack H. Dressel.....Colo. Sch. Mines
Mukunda B. Dutt.....Ohio State
Honorato S. Echavez (Rein.)
Univ. Kans.
A. B. Echols, Jr.....Okla. A&M
Frederick W. Elton.....Colo. Sch. Mines
Edward W. Ely.....Colo. Sch. Mines
Francis P. Embree.....Columbia Univ.
Homer C. English.....Univ. Okla.
Eric F. Engbrecht.....Univ. N. Dak.
John W. Felmet, Jr.....Ohio State
George H. Fentress....Colo. Sch. Mines
Lewis I. Field, Jr...Carnegie Inst. Tech.
George E. Fish.....Mo. Mines & Met.
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Ralph C. Flow.....S. Dak. Sch. Mines
Frank A. Foley.....Colo. Sch. Mines
William R. Foley...Carnegie Inst. Tech.
Robert L. Fossl.....Mo. Mines & Met.
Arthur L. Franks.....Mo. Mines & Met.
Marshall M. Frasier.....Okla. A&M
Reese L. Freeland, Jr.....Univ. S. Calif.
E. L. Frey, Jr.....Univ. Ill.
John E. Frost.....Stanford Univ.
Russell J. Gamberg...S. Dak. Sch. Mines
Larry A. Garfield.....Colo. Sch. Mines
Lowell W. Gibbs.....Univ. Minn.
Ernest R. Glabau.....Lafayette Coll.
William A. Gloe.....Univ. Wis.
Glenn R. Gobble.....Ohio State
James H. Goble.....Okla. A&M
Jesse H. Gravely.....W. Va. Univ.
Walter V. Green.....Univ. Wis.
Charles A. Greenlee.....Ohio State
Thomas L. Gregory.....Iowa State
Jack S. Griggs.....Univ. Okla.
Max L. Grimshaw.....Ill. Inst. Tech.
Marius P. Gronbeck...Mo. Mines & Met.
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John N. Hansen.....Univ. Wis.
Glenn M. Hanson....S. Dak. Sch. Mines
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Wayne D. Hart.....Mo. Mines & Met.
Robert H. Haubrich.....Univ. Wis.
Richard G. Heath.....Ohio State
Robert E. Hebert.....Mo. Mines & Met.
John J. Henderson..Texas Mines & Met.
George W. Herbst.....Univ. Minn.
Leonard F. Herzog, II.....MIT
Albert J. Higgins....Mo. Mines & Met.
Gerald Hoffman.....Colo. Sch. Mines
Clement Hofmann.....Colo. Sch. Mines
Thomas A. Holmes....Mo. Mines & Met.
John J. Hooten.....Okla. A&M
Marcus Hoppes.....Univ. Kans.
Paul S. Hopson.....Okla. A&M
William E. Horst.....Mo. Mines & Met.
David M. House.....Okla. A&M
Harold B. Houston.....Okla. A&M
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Walter E. Hyde.....Okla. A&M
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Donald A. Jess.....Univ. Idaho
Howard R. Johnson....Colo. Sch. Mines
John E. Kaites.....W. Va. Univ.
Leonard F. Kane.....Mo. Mines & Met.
Elias L. Kapernaros...Mo. Mines & Met.
William B. Kays, Jr....Colo. Sch. Mines
Peter O. Kirchhoff.....Univ. Wis.
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John W. Knack.....Univ. Wis.
Michael C. Kopchak.....Ill. Inst. Tech.
Walter A. Kramer....Mo. Mines & Met.
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Charles O. Kunz....Mo. Mines & Met.
Ralph W. LaCrone, Jr.....Okla. A&M
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William G. Lang.....Univ. Ill.
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Richard W. Martini.....Univ. Wis.
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Thomas J. McCroden...Stanford Univ.
Ross M. McDonald....Colo. Sch. Mines
Elwin D. McKnight.....Texas A&M
John A. Michelson.....Ohio State
John R. Mihalisin.....Yale Univ.
Roy G. Miles.....Mo. Mines & Met.
Daniel N. Miller, Jr...Mo. Mines & Met.
Melbourne W. Miller..Colo. Sch. Mines
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Charles R. Mitchell.....Univ. Ill.
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Thorsten L. Neyman.....Univ. Minn.
Richard C. O'Brien...Mo. Mines & Met.
William H. Osmus.....Univ. Calif.
Harry B. Owens, Jr.....Okla. A&M
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Robert L. Owens.....Lafayette Coll.
Malcolm F. Parkman.....Wash. State
William G. Paulsell..Mo. Mines & Met.
George T. Peart.....Colo. Sch. Mines
John A. Pederson.....Univ. Wis.
Emil Perout.....Univ. Cinn.
John H. Peterson.....Univ. Wis.
William R. Peterson.....Ohio State
Marvin N. Peyser.....CCNY
Richard P. Phillips....Stanford Univ.
Francis L. Pierson..Texas Mines & Met.
Max D. Pierson...Texas Mines & Met.
Philip C. Pierson.....Ohio State
Richard A. Pinto.....Yale Univ.
Charles H. Pitt.....Univ. Wis.
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J. R. Ramsey.....Mo. Mines & Met.
Robert J. Rankin.....Univ. Nev.
James H. Ratchen.....Ohio State
Raymond W. Reed....Mo. Mines & Met.
Robert H. Regan.....Mo. Mines & Met.
Jay L. Reiss.....RPI
Stanley F. Reiter.....Yale Univ.
George R. Remarcke.....Univ. Minn.
William F. Ricketts, Jr.
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Harvey V. Risien.....Texas A&M
Gilman C. Ritter (Rein.)...Univ. N. Dak.
Harry L. Rose.....Mo. Mines & Met.
John R. Ross.....Colo. Sch. Mines
Kermit G. Rowley....Mo. Mines & Met.
James H. Roy.....Univ. Idaho
Paul E. Ruff.....Ohio State
Fred E. Rugg.....Colo. Sch. Mines
John R. Salvaggi....Mo. Mines & Met.
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Richard D. Sawyer.....Univ. S. Calif.
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William A. Schrader, Jr.....Univ. Wis.
David B. Schulz.....Colo. Sch. Mines
Eugene A. Scussel..Texas Mines & Met.
Henry J. Scussel..Texas Mines & Met.
John Sedor, Jr.....Ohio State
Berman J. Shafer.....Ohio State
Marlow E. Sharpe.....Colo. Sch. Mines
William M. Shepard...Mo. Mines & Met.
James C. Shepherd.....Univ. Kans.
Henry M. Shillinglaw.....Univ. Wis.
Merton I. Signer, Jr....Colo. Sch. Mines
James N. Siltanen.....Ill. Inst. Tech.
Charles C. Simpson, Jr.....Univ. Ala.
Thomas G. Sinclair.....Texas A&M
Walter J. Smit.....Texas Mines & Met.
Arthur C. Smith.....Univ. Ariz.
Bertram L. Smith, Jr....S. Meth. Univ.
Jake R. Smith.....Colo. Sch. Mines
John G. Smith.....Colo. Sch. Mines
Lowell T. Smith.....Mo. Mines & Met.
Oziel L. Smith, Jr.....Okla. A&M
Stuart A. Smith.....Yale Univ.
Verne L. Snow.....Okla. A&M
Gerald W. Spotts.....Okla. A&M
James T. Stanley.....Univ. Ill.
Walter L. Steinhilber.....CCNY
Norman C. Stevenson..Okla. Inst. Tech.
Raymond M. Stewart..Colo. Sch. Mines
Bobby G. Stoops.....Okla. A&M
Robert R. Strange.....Ohio State
Erwin J. Strecker.....Univ. N. Dak.
James R. Stringham....Colo. Sch. Mines
Hung-Shung Sung.....Ohio State
Horace Sutcliffe, Jr.....Univ. Ala.
Theodore M. Swanson.....Univ. Minn.
Charles A. Tallard.....Univ. Minn.
Yeshwant P. Telang.....Univ. Mich.
Paul J. Theusen.....Mo. Mines & Met.
Mitat Y. Tolgay.....Mo. Mines & Met.
Emery M. Tower, Jr.....Okla. A&M
John F. Townsend.....Okla. A&M
James W. Tracey.....Okla. A&M
Jack K. Trotter.....Mo. Mines & Met.
John Turyn, Jr.....W. Va. Univ.
Robert VanNostrand (Rein.)
Mo. Mines & Met.
Ray J. VanThyne.....Ill. Inst. Tech.
Oscar M. Villareal..Texas Mines & Met.
Herbert N. Wade.....Texas A&M
Edward Walther, Jr.....Univ. Ala.
Norman F. Warren.....Univ. Nev.
Justin E. Weatherly, Jr....Texas A&M
Keith T. Webb.....S. Meth. Univ.
Robert I. Weiner.....RPI
Franklin J. Weinhaupl..Colo. Sch. Mines
Herman E. Wendy.....Texas A&M
Samuel W. West.....Okla. A&M
Robert D. Whitmer...Mo. Mines & Met.
Olen H. Whitmire..Texas Mines & Met.
Alexander Wiegel.....Ill. Inst. Tech.
Donald E. Williams.....Ohio State
Gerald M. Wilson....Mo. Mines & Met.
Harold S. Winston.....Univ. Minn.
John S. Winston.....Mo. Mines & Met.
John C. Wright.....Ohio State
John H. Wyatt.....Colo. Sch. Mines
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Underground Anemometry*

BY CLOYD M. SMITH,† Member AIME

A FEW years ago, the Ventilation Committee established the practice of presenting one topic each year for discussion at the annual meeting. The practice has met good response on the part of committee members and I suggest that it be continued. The topic chosen for this year, "Underground Anemometry," is a topic which has bothered me for more than 20 years. It seems to me that the coal industry is content to rely on slipshod methods for measuring the rate of flow of air underground, so I prefaced my discussional charge to committee members with the statement that I regard air measurements made in the usual way, with hand held anemometer, as no good. Agreements and disagreements came in from more than a dozen engineers, some of whom are with operating companies, coal and metal; some with manufacturers; others with government agencies.

The statement was accompanied by a questionnaire on the use of the rotating vane anemometer and by one describing two methods of using a mechanically held anemometer. The questionnaire will be considered first. The questionnaire and statement are as shown on pages 5 and 6, the committee members and respondents are given on page 4, and the general comments of the latter on page 5.

Questionnaire

1. *Has your company or agency issued written instructions for care and use of anemometers? If so, please enclose a copy with reply.*

Only one answer, McElroy's, was affirmative. It gave reference to Bureau of Mines publications[1,2] which recommend the hand held anemometer for rough measurements and indicate that an accuracy of 5 pct can be had if calibration and method factors are used.

Mathews said that instructions are principally oral while Maize reported that state inspectors of his department are well trained in use and care of anemometers.

2. *Are your anemometers calibrated periodically? If so, by their manufacturer? or by? Are calibration corrections applied to all observed mean velocity readings?*

Only one respondent, Lee, answered negatively as to calibration. This means that anemometers are generally calibrated but the questionnaire failed to ask how often this is done. As no one volunteered the information, we have no data on this point. In six cases the instruments are sent to their manufacturers for calibration, but Krickovic reports that his company limits manufacturers' calibrations to anemometers which are used by operating personnel; those used by the engineering department being calibrated by U. S. Bureau of Standards. The Anaconda Copper Mining Co. has its ventilation engineers calibrate its anemometers.

Most of the respondents say that a calibration correction is applied to each mean velocity reading, but Krickovic limits this to surveys made by the engineering department. Since Lee does not calibrate, he has no correction to apply. Maize reports that his department has its anemometers calibrated but does not apply corrections.

3. *Do your men hold the anemometer by hand in measuring air flow? for 1 min? or traverse the section? for 1 min? or at? points for 5 sec each?*

Of 10 replies, 6 were "yes," 3 were "no," and one was "seldom" with respect to holding by hand. Among the six hand holders, four hold in a central position in the measuring section for a minute, except that two of them, Krickovic and Matthews, traverse the section by hand for survey or fan test. Their operating personnel hold by hand, centrally, for routine measurements. McElroy sometimes traverses with hand-held anemometer in rapid survey work.

4. *If the anemometer is not held by hand, how is it supported?*

Augustadt supports the anemometer on an adjustable rod, Condon on "a rod of sufficient length to reach all points with observer standing in one position throughout traverse and at arm's length from plane of traverse." I presume that arm's length must be interpreted liberally enough to allow for arm movement, otherwise it would be impossible to manipulate the anemometer throughout the traverse section. Mancha upholds Condon in this method of traversing. Glanville hangs the anemometer on the end of a 4-ft staff by the hasp at the top of the anemometer frame. McElroy mounts it on the end of a rigid square shaft, 12 in. long, the staff being at right angles to the axis of the instrument. He traverses the section in two halves, holding the anemometer 3 feet from his body.

New York Meeting, February 1948.
TP 2502 F. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before April 1, 1948.

* Statement of personal views presented at the annual meeting pursuant to study of replies to questionnaire submitted to members of the Ventilation Committee of the Coal Division, and to others. Manuscript received May 17, 1948, revision, Sept. 8, 1948.

† Chairman, Ventilation Committee, Coal Division AIME; Mining Engineer, Washington, D. C.

[1] References are at the end of the paper.

5. *Is each initial determination repeated immediately after it is taken, as a check? If so, can you supply data on the self consistency of such measurements, i.e., how well do the repeat runs check the first runs?*

Most observers take check readings, but Matthews limits them to tests for new fan installations. As to consistency of results, Beckwith reports thousands of checks within 5 pct, Krickovic reports checks within 10 to 15 pct, pointing out that perfect checks would not ensure accuracy since both readings might be equally wrong. Matthews reports checks on 4 or 5 readings within 5 to 10 pct with the anemometer held "on a stick." The best consistency is reported by Condon as follows:

Mean velocity range, fpm	under 500	500–1500	over 1500
Consistency within, pct	0.5	1.0	2.0

Field notes submitted by Glanville covering 11 paired traverses of as many sections at mean velocities ranging from 264 to 1250 fpm show 5 pairs in which the readings are within 1 pct of each other; 3 pairs within 2 pct; and 1 pair each within 3, 7 and 9 pct. The last two were known to be affected by haulage movements. Richardson reports that variations are usually less than 5 pct, commonly 2 pct, with a stick-mounted instrument. Under similar conditions McElroy reports checks within 1 pct for good conditions and within 2 pct for poor conditions by an experienced operator.

6. *Has your company or agency issued instructions for choice of measuring section, covering such points as desirable approach and departure conditions, freedom from obstructions, preferable shapes and dimensions, and methods of determining cross-sectional area? If so, please enclose a copy with reply.*

Only Beckwith reported issuance of instructions for selection and measurement of air measuring sections and those instructions are mainly oral.

7. *Do your men take air measurements in or near regulator openings? If so, directly in the opening or how far downstream from it?*

There were four flat negatives and three flat positives in the answers to this question. In one of the latter cases reported by Beckwith the measurements are made in, not near, the regulator opening. Maize states that measurements are taken in the regulator opening only when a small volume of air is flowing and that, if velocity of the air is high as it enters the regulator, measurements are taken far enough away for the readings not to be affected. No indication is given as to how far from the regulator this must be, whether upstream or downstream, nor is there any indication as to what are regarded as high and low velocities and quantities. Krickovic reports taking readings near regulators at times, but ordinarily from 100 to 200 ft downstream according to the velocity. Matthews states that they are not taken within 50 ft of a regulator, while McElroy reports that regulators are avoided if possible but that door frames are acceptable. Readings are taken at the downstream edge of the regulator or frame, when these locations are used.

9. *How are sections measured to determine their areas? By tape only? by plumb bob and tape? or by special instrument or methods? If special methods are used, please describe.*

Most respondents measure sections for determination of cross-sectional area with tape only. Condon measures irregular areas by using the maximum width and average verticals taken at 1-ft intervals along the width. Glanville uses plumb bob and tape, then plots the cross section and determines its area by planimeter. McElroy uses plumb bob and tape for fan tests and a specially designed pantograph[3] for research. A comparable research method is described by Callen and Smith.[4]

10. *General remarks.*

Glanville reports close checks in traversing with anemometers and Pitot tube at high velocities and cites two instances:

(a) A Pitot tube traverse in the casing of a high-speed high-pressure propeller-type fan and an anemometer check in a carefully planimetered section 60 ft outby the fan.

Pitot tube air volume	61,100 cfm
Anemometer air volume	59,700 cfm
Difference	2.3 pct

(b) Exhaust of a fume collecting duct 14 by 14 in. square.

Pitot tube air volume	4,805 cfm
Anemometer air volume	4,897 cfm
Difference	1.1 pct

Richardson states: anemometers are calibrated at the end of a small diameter duct against velocity head by Pitot tube. The instruments are cleaned and lubricated as necessary by a watchmaker. A dirty anemometer can give very erroneous readings. High and low speed anemometers should be used according to air velocities. Continuous movement through a traverse does not check out as well as point by point traversing against Pitot tube at a measuring station.

Statement on Traversing

The questionnaires were mailed out with a statement titled "Underground Anemometry" (for the complete statement see page 6) which described two methods of traversing with mechanically supported anemometer and recommended that the two methods be tested against Pitot tube traversing. The major part of this statement is reviewed in three sections in the light of group discussion as follows:

1. The rotating vane anemometer has been the principal instrument for measuring rates of air flow in mines since the earliest days of systematic ventilation, and it has won an indispensable role in that field. However, it is one of the most abused of engineering instruments, and a shamefully small amount of thought has been devoted to its use. The principal abuse of the anemometer lies in its being held in the hand during registration, a method which brings the operator's body so close to the measuring section and to the instrument as to disturb the flow of air through the section and past the instrument and thereby to distort the results. Whether the hand-held anemometer is held in one position or traversed about the section, there is sufficient evidence to rule out this method of air measurement for any but the roughest estimates of rates of flow. Nevertheless, the anemometer is held by hand by company, state, and federal inspectors in thousands of mines daily.

These contentions with respect to manual anemometry are questioned by Beckwith who asks for the evidence which rules out this method from the standpoint of accuracy. This evidence was presented 20 years ago by Calles and Smith.[5] As far as I know, their work is the only published comparison of hand anemometry with another method, in this case Pitot tube traversing. The reports show traversing

with the hand-held anemometer to have given average mean velocities which were 19 to 29 pct greater than those determined with Pitot tube at three traverse sections at mean velocities in the range of 500 to 1100 fpm. More than 100 anemometer traverses were run, holding the anemometer by hand and traversing first one-half then the other half of the section to keep the instrument at arm's length while it was registering. Different anemometers and observers were used at sections of varied shapes and rates of flow. Not only were the anemometer results surprisingly in excess of the Pitot tube results, but they were far less consistent. As indicated in the published report, they were so bad as to discourage further anemometer work. However, Beckwith, Krickovic, and McElroy report consistent results with hand traversing, although Krickovic recognizes that self-consistency of a method has no bearing on its accuracy, in that it may be consistently wrong as well as consistently right.

2. If accurate results are to be had, the anemometer must be supported mechanically and the measuring section must be traversed. Traversing is usually done by holding the anemometer for 5 sec in each of several well-distributed positions in the measuring section. Two methods of mechanically supporting the anemometer in the section during traversing are in use. In one the instrument is hung from the end of a long stick or rod by a hasp at the top of the anemometer frame in such a way that the instrument's axis of rotation and the supporting rod are in a vertical plane parallel to the direction of flow. In traversing, the operator moves the instrument from point to point in the measuring section, while standing well downstream from the section. As nothing but the anemometer is introduced into the measuring section, this method will be referred to as the clear section method of traversing.

Krickovic insists that a section which is to be so traversed must be specially prepared, but states that many years of experience have shown that good results can be expected in any well chosen traverse section with only the preparation which would normally be given a section before it is measured, such as checking the top, smoothing the floor and knocking loose coal from the ribs. Column points are marked 2 to 4 ft apart across the roof, according to the width of the section and the anemometer is held under each roof mark for 5 sec at each point in a succession of points which are spaced approximately 2 ft apart vertically. The anemometer progresses from column to column until the traverse is completed. The method has proved to be widely applicable, expeditious, and simple.

Condon raises the point that gravity suspension permits the anemometer to swing out of plumb so that its axis is inclined to the direction of flow, and that swinging may introduce pulsating velocities through the instrument. Whether this introduces errors of appreciable magnitude awaits investigation. McElroy proposes moving the anemometer slowly up and down along vertical lines 1 or 2 ft apart as an alternative to holding it in successive points in each column. Whether this is preferable to point traversing should also be determined.

3. In the other method[6] the instrument is rigidly attached to the end of a long stick or rod by a screw socket on the cylindrical frame of the anemometer in such a way that the rod is perpendicular to the axis of vane rotation. In traversing, the operator stands centrally in the passage close enough to the measuring section to hold the rod and instrument in the section and to move the anemometer from point to point without shifting his feet and with minimum bodily movement. Inasmuch as he must essentially stand in the section, facing the air stream, this will be referred to as the obstructed section method.

Krickovic feels that equally good results could be obtained by extending the arm instead of using a rod. However, in the view of the author, the operator would have to move his body to cover any but unusually narrow sections whereas the crux of the method is that the operator should remain motionless so that a fixed rate of flow will prevail in each point of the section. The more nearly he stands still the more nearly the flow pattern remains constant throughout the traverse. While the pattern differs from the normal that exists with no one in the passage, the difference is immaterial so long as the pattern remains fixed during traversing and so long as the section is adequately traversed to give a true mean velocity. Necessary movement of the hands and arms in traversing and bodily movements are minimized.

Condon points out a source of error in inability of the operator to gauge visually the angle between the axis of the instrument and the direction of flow and to maintain parallelism. This

Table 1 . . . Classification of Methods of Traversing with Mechanically Held Anemometer

Basis	Reference	Essence	Name
Approach of operator to section and degree of consequent bodily interference with flow.	I	Operator 4 to 5 ft downstream from section; minimum feasible interference with flow through section but changing pattern.	Clear section.
	II	Operator 1 to 2 ft downstream from section; interference with flow through part of section but fixed pattern.	Obstructed section.
	III	Operator in section in 2 positions, successively; interference with flow through part of section; 2 patterns; traversing in clear part of section only.	Obstructed section.
Method of anemometer support.	I	Gravity suspension of anemometer by hasp. Supporting rod (ca 6 ft) and axis of instrument are in vertical plane which is perpendicular to traverse section.	Suspended anemometer.
	II	Rigid attachment of anemometer frame to end of (ca 6 ft) rod. Rod in traverse section. Axis of instrument perpendicular to rod.	Attached anemometer.
	III	The same except short rod (ca 1 ft).	Attached anemometer.
Positioning of operator.	I	Operator 4 to 5 ft downstream from section immediately behind each traverse column, ordinarily 4 or 5 operator positions.	Multiple position.
	II	Operator 1 to 2 ft downstream from section, midway of entry. Negligible bodily movement.	Single position.
	III	Operator in section first to 1 side of instrument then to other; crouches to shift between positions.	Dual position.

error is akin to the error he cited in the other method due to swing of the anemometer. Both await valuation.

McElroy (Table 1 reference No. III) proposes a third method of traversing with mechanically supported anemometer. That is to screw the instrument onto a short rod, instead of a long one as in the second method, and to have the operator stand in the section and hold the anemometer at arm's length while slowly backing across the section to about midsection, then to change position by crouching and passing the anemometer above his body, thereafter to advance slowly, moving the anemometer up and down to complete the traverse.

Mancha takes exception to the nomenclature used in designating the methods on the grounds that the term "obstructed section method" is prejudicial. Two other bases of nomenclature suggest themselves:

1. The method of support of the anemometer.

2. The number of positions occupied by the operator during traversing.

Two methods of mechanical support are under consideration, suspension and attachment, while three classes of operator positioning are involved. The situation is analyzed in Table 1. Since the positional basis of classification is the only one that gives three names, single, dual and multiple-position, for the three methods, its use is suggested pending the devise of a better system.

Proposal for Investigation

As to choice of traversing methods the answer would seem to lie in direct comparison of these methods and of other methods which may be proposed, including manual holding, with results of Pitot tube traversing in a specially prepared and instrumented mine passage or wind tunnel. This is a small research project which the industry should undertake as a step toward putting its measurement of air flow on a sound basis. That it is on no such basis now is highlighted by Harrington who says:

> Anemometer air measurements of the usual kind, by holding the instrument in the hand usually with the body in the air stream, are mere approximations and this is true to even a greater extent of the usual tape measuring of the cross sectional area. These two *guesses* are multiplied together and the quantity thus secured is at best a not particularly close approximation as to the actual quantity.

He goes on to say that this is not a matter of much practical concern, but I do not hold with the view that it is immaterial whether quantity measurements are 20 to 30 pct off, nor do I hold with those who insist that coal mine supervisory employees are too dumb to learn a simple accurate method of traversing if one is developed. It is my notion that any man who can properly care for and use a flame testing lamp can also do good work with a vane anemometer, once he is taught how. The investigation I propose should result in a method of underground traversing with the rotating vane anemometer which will be generally applicable to and acceptable for fan testing and ventilation surveying, and it should lead to a simple but reasonably accurate method of traversing for use by operating personnel in making routine quantity measurements as required by law; a method which will give better and more dependable results than the present haphazard work.

There is not space enough to permit further discussion nor complete treatment of the general comments which many members of the group submitted. In closing, I want to explain that I took the liberty of including some nonmembers of the committee, indeed of the Institute, in the group in view of their known interest and competence in the subject and I want to thank members and nonmembers alike for their splendid help. I also want to warn that this statement is the report of the chairman, not of the committee, and it is therefore primarily expressive of his views. No committee member has seen it nor has responsibility for it, but it is hoped that it will meet approval of the committee as a whole. It is respectfully submitted for committee disposal.

List of Committee Members and Respondents

Ventilation Committee Members:

Alfred T. Beckwith, Special Engineer, Lehigh Navigation Coal Co., Lansford, Pa.

John W. Buch, Supervising Engineer, Anthracite Mechanical Mining Section, U. S. Bureau of Mines, Schuylkill Haven, Pa.

Stephen Krickovic, Chief Engineer, Koppers Coal Co., Pittsburgh, Pa.

Raymond Mancha, Vice President, Joy Manufacturing Co., Pittsburgh, Pa.

Charles H. Matthews, Electrical and Mechanical Engineer, Susquehanna Collieries Co., Nanticoke, Pa.

F. C. Sturges, Vice President, Pennsylvania Drilling Co., Pittsburgh, Pa.

Cloyd M. Smith, Consulting Engineer, Washington, D. C., Committee Chairman.

The following who are not members of the committee contributed to the discussion on invitation:

G. L. Augustadt, Ventilation Engineer, Magma Copper Co., Superior, Ariz.

R. E. Condon, Manager of Sales, Ventilation Division, Jeffrey Manufacturing Co., Columbus, Ohio.

Leo Glanville, Ventilation Engineer, Climax Molybdenum Co., Climax, Colo.

Daniel A. Harrington, Chief, Health and Safety Branch, U. S. Bureau of Mines, Washington, D. C.

Carl Lee, Chief Engineer, Peabody Coal Co., Chicago, Ill.

Richard Maize, Secretary of Mines, Harrisburg, Pa.

* G. E. McElroy, Supervising Engineer, Mine Ventilation Section, Health Branch, U. S. Bureau of Mines, Pittsburgh, Pa.

Allan S. Richardson, Ventilation Engineer, Anaconda Copper Mining Co., Butte, Mont.

* Became member of committee March 3, 1948.

Omaha Public Library
Reference Dept.

General Comments by Respondents

A. T. Beckwith—I cannot agree that holding the anemometer in your hand is no good, inasmuch as my own experience with this method has been contrarywise. Following are my viewpoints on the matter:

The standard rotating vane anemometer is a precision instrument; the application of this instrument to its function of measuring air flow is a science. Mainly because of a lack of knowledge as to what constitutes good practice, the majority of men who take anemometer readings obtain inferior results.

In recent years I have made several thousand air quantity measurements by hand-holding anemometers, and have found, by repeat measurements and the split flow method of checking results, that such measurements can be expected to consistently balance out within 5 pct. This degree of accuracy, I believe, is sufficient for all requirements in the average mine, with the possible exception of the measurements made to determine fan performance.

A first consideration toward obtaining a measurement of air flow is selection of the measuring station in the available portion of the air course. Frequently a measurement is desired in a section of the workings wherein but a short length of air course is available because of the proximity of one split to another. When, of necessity, the station has an irregular outline, has nearby obstructions, or is in a curved air course, the undesirable conditions must be recognized as such. Measurements of the splits at satisfactory locations are useful in arriving at the quantity of flow by sum or difference.

In rock tunnels or other such type air courses, there may be a section several hundred feet long in which the measuring station may be located. The available length of air course should be visually inspected, and the most promising spot selected. Customarily some one spot will stand out as a best location.

After having selected and marked stations in two different mines, I had occasion three years later to resurvey the ventilation. In most places the old paint or chalk marks which I had placed on the ribs were laden with dust, and were not discernible to one passing by. In selecting the new stations, however, invariably the same site would be chosen as had been used before, as evidenced by discovering the old station markings along side the new ones.

Great care must be exercised when locating stations in timbered air courses, because at a timber set the blocking between cap and roof, legs and ribs may not be closely spaced. Considerable air may be passing through these openings, and, of course, this air flow would not be

Questionnaire and Statement Which Formed the Basis for This Paper

QUESTIONS ON USE OF ANEMOMETERS

1. Has your company or agency issued written instructions for care and use of anemometers?_____ If so, will you please enclose a copy with your reply.

2. Are your anemometers calibrated periodically?_____
   a. If so, by their manufacturer?_____
   or by?_____
   b. Are calibration corrections applied to all observed mean velocity readings?
   _____

3. Do your men hold the anemometer by hand in measuring air flow?_____
   a. If so, do they hold it in one central position?_____
   for 1 minute?_____or traverse the section?_____for 1 min?_____
   or at?_____points for 5 seconds each?_____

4. If the anemometer is not held by hand, how is it supported?_____
   _____

5. Is each initial determination repeated immediately after it is taken as a check?
   _____
   a. If so, can you supply data on the self-consistency of such measurements, i.e., how well do the repeat runs check the first runs?_____
   _____

6. Has your company or agency issued instructions for choice of measuring section, covering such points as desirable approach and departure conditions, freedom from obstructions, preferable shapes and dimensions and methods of determining cross-sectional area?_____
   If so, will you please enclose a copy with reply.

7. Do your men take air measurements in or near regulator openings?_____
   a. If so, directly in the opening or how far downstream from it?_____

8. Do your men accept measuring sections which are partly obstructed by a prop or props in the section or within a foot or two of it?_____
   a. If so, do they deduct the area or projected area of the prop or props in computing net area of the section?_____

9. How are sections measured to determine their areas?_____
   By tape only_____; by plumb bob and tape_____; or by special instrument or methods_____? If special methods are used, please describe_____

10. General remarks_____

measured in the anemometer traverse. Smoke apparatus may be advantageously employed to disclose such conditions.

When a station is selected in an untimbered location, vertical lines opposite each other are placed on the ribs to guide the operator during the traverse.

The cross-sectional area of the station may be determined by using a tape graduated in feet and tenths of a foot. The degree of regularity of the section contour will determine the number of measurements to be taken. For most mine openings, one or two vertical measurements and from 2 to 6 horizontal ones will suffice.

The station should be traversed, and a repeat measurement made.

The man running the traverse may hold a watch in his free hand, or a second man may stand close by the rib, well downstream, and call out the time.

The ability of an operator to move the anemometer at a steady rate and to form a pattern so as to cover adequately the entire cross-sectional area, and complete the traverse on time, after covering, once or twice, the entire section, is a skill which can come only with continued practice.

If the station has sufficient height, the operator may pivot with the anemometer overhead while midway through the traverse, in order to cover the entire section with the instrument and complete the traverse with the anemometer along the second rib. Otherwise, he should start at one rib and end the traverse with the anemometer close by himself as he backs up against the second rib, then reverse sides, and average the results.

The operator can easily hold the anemometer so as to start and stop its recording mechanism with the index finger of the same hand which holds the machine. In spite of this, many men will fumble around when starting and stopping the instrument, disturbing the air flow and getting 65 sec or so of recording into what is supposed to be 60 sec worth.

Probably the greatest abuse, however, is that the operator, rather than passing the instrument through a definite traverse pattern, will whisk the anemometer about haphazardly in the central part of the station. Such practice obviously cannot result in obtaining accurate air measurements.

The velocity recorded on the anemometer must be adjusted to a true value by using the calibration correction for the instrument.

A "method" factor must be used also to compensate mainly for distortion of the recording through hand-holding instrument. By reducing the full measured cross-sectional area by 4 sq ft, a simple and suitable arrangement has been established which will take care of the method factor for all standard conditions.

Some measurements must be made in very small openings, in inclined openings, or in locations having other poor natural

December 6, 1947

UNDERGROUND ANEMOMETRY

BY CLOYD M. SMITH

Description of two methods of using the rotating vane anemometer for measuring rates of air flow in mines and proposal for investigations.

Submitted to members of Ventilation Committee, Coal Division, AIME, and other interested parties for discussion.

The rotating vane anemometer has been the principal instrument for measuring rates of air flow in mines since the earliest days of sytematic ventilation, and it has won an indispensable role in that field. However, it is one of the most abused of engineering instruments, and a shamefully small amount of thought has been devoted to its use. The principal abuse of the anemometer lies in its being held in the hand during registration, a method which brings the operator's body so close to the measuring section and to the instrument as to disturb the flow of air through the section and past the instrument and thereby to distort the results. Whether the hand-held anemometer is held in one position or traversed about the section, there is sufficient evidence to rule out this method of air measurement for any but the roughest estimates of rates of flow. Nevertheless, the anemometer is held by hand by company, state and federal inspectors in thousands of mines daily.

If accurate results are to be had, the anemometer must be supported mechanically and the measuring section must be traversed. Traversing is usually done by holding the anemometer for 5 sec in each of several well-distributed positions in the measuring section. Two methods of mechanically supporting the anemometer in the section during traversing are in use. In one the instrument is hung from the end of a long stick or rod by a hasp at the top of the anemometer frame in such a way that the instrument's axis of rotation and the supporting rod are in a vertical plane parallel to the direction of flow. In traversing, the operator moves the instrument from point to point in the measuring section, while standing well downstream from the section. As nothing but the anemometer is introduced into the measuring section this method will be referred to as the clear section of traversing.

In the other method the instrument is rigidly attached to the end of a long stick or rod by a screw socket on the cylindrical frame of the anemometer in such a way that the rod is perpendicular to the axis of rotation. In traversing, the operator stands centrally in the passage close enough to the measuring section to hold the rod and instrument in the section and to move the anemometer from point to point without shifting his feet and with minimum bodily movement. Inasmuch as he must essentially stand in the section, facing the air stream, this will be referred to as the obstructed section method.

Both methods have advantages and disadvantages. The clear section method leaves the pattern of flow through the measuring section unaffected if the operator stands a sufficient distance downstream from the section. This reduces to a minimum acceleration and deceleration of the rotating parts of the anemometer due to changes in air speed from point to point. This is conducive to accuracy. An objection to the clear section method is that the operator stands directly downstream from the instrument so that failure to have a support long enough to remove the upstream effect of the operator's body from the traverse section affects the registration. The error is minimized by lengthening the support but requirements of convenience limit its length to a little more than 6 ft. A theoretical objection to the clear section method is that the operator moves from one side of the passage to the other in traversing. In doing so he gets into zones of different velocity, and presumably sets up differing resistances to flow which could affect the rate of flow. This effect is presumably negligible, but it is subject to investigation.

The obstructed section method has the theoretical advantage of maintaining constant flow within the system during traversing but it has the disadvantage of setting up an abnormal flow pattern in the traverse section. The abnormality comes about from the fact that the operator must stand so close to the section that he obstructs flow in the part of the section that is in front of his body. This speeds up flow else-

where in the section and sets up steep velocity gradients between the area directly in front of him and the adjoining portions of the section. Such gradients call for a finer network of traverse points than would otherwise be required and they lead to rapid acceleration and deceleration of rotating parts of the anemometer when it is moved between obstructed and clear points. Rapid changes in speed induce instrumental error and impair application of calibration corrections.

The obstruction of flow in front of the operator may be such that the vanes of the anemometer come to a full stop while the instrument is stationary during 5-sec period. It would seem that such an abnormal flow pattern would make it impossible to get accurate results, but apparently the method can be made to yield acceptable mean velocities.

In both methods the operator must leave his normal position at the beginning of a traverse to start anemometer registration and at the end to stop it, but this requires only 2 or 3 sec at each end of the traverse so the percentage of total time involved is small. It is probable that neither method is better than the other in this respect.

The two methods should be proved against rates of flow determined by Pitot tube traversing. To do this, underground measuring stations should be established in which rates of flow could be measured by Pitot tube and by the two methods of anemometer traversing at different rates of flow. A range in mean velocity from 100 to 2000 fpm would be ample. The tests should also be run in sections of different size and shape, ranging from 5 by 7 to 10 by 12 ft in cross section. Comparison of tests run with calibrated anemometers by several observers using both methods should lead to conclusions as to superiority of one method over the other from the standpoints of accuracy, consistency of results, and adaptability to use by miscellaneous operators.

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characteristics. It would be extremely difficult to attempt to set up definite procedures for such cases, and the individual must rely on his judgment as to how he will proceed, and must also evaluate, on the basis of his experience, the validity of measurements so obtained.

It is well to mention here, too, that too frequently anemometers are used to measure low-velocity air currents to which they are unsuited. Such low-velocity currents can be measured suitably with smoke apparatus.

Unquestionably there is much to be learned concerning the best methods for using anemometers, and tests, under controlled conditions with the various methods available, would certainly bring out much valuable information.

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STEPHEN KRICKOVIC—I believe your subject matter should be clarified from the standpoint of job to be done. If a fan test is to be run or if total volume entering or leaving the mine is desired, greater accuracy is needed than in measuring air volumes throughout the mine. For the latter, I have found traversing of an area twice per minute at a uniform rate of speed, but without marking off the area into a number of uniform squares, with one or two immediate checks is perfectly satisfactory. Actually, I have obtained good results by the same method on fan tests. Generally, however, fan test volumes, if not obtained by Pitot tube, should be measured in the divided areas.

It is to be noted in all of this work that an accuracy of 5 to 7 pct is generally satisfactory.

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RAYMOND MANCHA—The following is my appraisal of the situation expressed in comparatively few words.

Body effect upon flow pattern extends considerably more than 6 ft upstream resulting in a continual shifting or changing flow pattern in the plane of traverse when employing what you describe as the "clear section" method of traversing with a constantly moving operator. This effect can be easily determined quantitatively by the application of existing formulas from the effect of obstructions in an air stream at various distances from said obstructions.

Complete or near stoppage of the anemometer held directly ahead of the "obstructed method" stationary operator, is entirely foreign to my entire range of practical experience. I have never seen an anemometer stop or even approximately stop when held at an arm's length ahead of me due to the presence of my body in the air stream.

My suggestion is why not combine advantages of both methods by conducting the clear section method with a stick sufficiently long to permit the operator to remain stationary throughout the traverse. This method should satisfy everybody, and from past experience I am convinced that the results so obtained should be in sufficiently close agreement with the results by the so-called "obstructed method" as to justify the use of this more wieldy practical method.

In summation, it has been my experience that the anemometer's accelerations and decelerations occasioned by body presence at arm's length below the instrument are of the same order of magnitude as instrument accelerations and decelerations experienced by the normal flow pattern encountered in the average mine airway where its measurements are made. For example, the instrument slows down considerably more upon approaching close to the roof or rib than it does when passing in front of the operator's body. And, furthermore, the stationary operator guarantees a steady flow pattern throughout the entire traverse, which I think outweighs the effects of the anemometer's accelerations and decelerations to which you refer.

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C. H. MATTHEWS—Once each month our section foremen check the flow of air at various pre-measured locations and we send a report to the state mine inspectors. If the flow of air does not correspond closely with previous readings a check is made by one of our mining engineers. Anemometers are sent to the manufacturer for calibration, but we have often found that the foremen do not always use the correction factor. The periodic tests made by our section foremen are really just an indication of air flow from month to month and errors may be in all of their readings.

When a new fan is contemplated, a fairly careful check is made to determine the pressure required for the flow of air requested by the mining department. The only need for great accuracy might be to check the performance guarantee of a fan. This is not as necessary today as it was 20 yr ago because the manufacturers have modern facilities for testing and can easily meet their guarantees.

We endeavor to provide adequate air where needed and to install fans that do not waste power.

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R. E. CONDON—Referring to your letter and to your very emphatic statement

that holding an anemometer in your hand is "no good," I cannot entirely agree with you in this statement, as I believe anemometer readings made in such a manner are very good for quickly determining the relative difference in volumes, or rather velocities from day to day, which actually is what the inside personnel of the mine are interested in. It tells them very quickly whether any unusual condition has come about in the short period of time since the last measurement was taken.

I do agree with you in that it is not an accurate way of determining the actual volume or velocity that is passing that particular point. I also believe that the areas measured at the measuring station lend as much inaccuracy to the readings as the method of taking anemometer readings.

In discussing your statement on "Underground Anemometry," I would say first that the same condition would apply when holding the anemometer in your hand as mentioned above. The error which comes into such readings varies considerably with the velocities that are being measured and, in my experience over many years, indicates that on velocities around 100 to 200 fpm, which are usually encountered near the working faces and with the large areas that are involved, the difference between the readings obtained in the hand method of taking readings and those obtained by mechanically supporting the anemometer, is very small. By this statement I mean the different readings would not vary more than 5 pct, which, of course, is still in favor of the mechanically supported anemometer.

Whereas, in velocities exceeding 1500 fpm, this same difference would vary as much as 30 to 40 pct in the same direction. In general, it is undebatable that the more accurate readings can be obtained with the mechanically supported anemometer.

In regard to the two different methods of supporting the anemometer for taking measurements, it is my experience that the one which you mention as being the obstructed section method, is the more practical one for everyday use and I believe is just as accurate as the clear section of traversing. Explaining further this statement, I find that very few mine operators are concerned enough about the accurate readings to such an extent that they will provide an ideal measuring station underground, and the net result is that one has to find the best location under existing conditions to obtain the readings. A good many factors must be considered when trying to locate such a station and I am happy to say that the recent trend brought about by the Department of Mines in specifying the fan to be offset a minimum distance of 15 ft from the near edge of the mine opening, has in a good many cases presented a better measuring station for air measurements, insofar as the actual volumes passing through the fan are concerned. This means there is sufficient space immediately upstream from the fan to take a volume reading, which would include practically all leakage air present in the ventilation system; whereas, if the readings were taken underground there is a possibility of a large leakage occurring between the point of measurement and the fan.

This same underground reading, however, without a doubt would be much more accurate in measuring the volume of air passing through the mine itself, providing usual precautions are taken when taking the measurements.

You have stated the common errors prevailing in using both of these systems and in either one extreme care must be taken in order to accomplish most accurate results. For the inexperienced operator I would suggest stretching strings across the area, which are used as guides when taking measurements. An experienced observer can take such readings either by using marks along the sides of the air course, or simply by using other marks of identification usually present in an air course.

It is my opinion that either of the methods stated should check very closely on successive readings and I believe should come within 2 pct, even on the higher velocities. I do believe that successive readings should be taken with the mine in operation, as local conditions quite frequently vary the readings considerably during the time interval required to make the traverse.

I believe your analysis and description of the two methods is very complete and I cannot think of anything more to add. I do believe, however, that there would be little gained as suggested in the last paragraph of your report, by establishing an underground station and testing the two different methods of taking the readings, because it might be misleading. In other words, there is no doubt in my mind that with such a perfect setup, both methods with experienced operators, would check very closely; whereas, I can think of a number of places under practical conditions, wherein one method would be better than another and it is my contention that wherever readings are taken, extreme care in handling instruments, taking measurements, and applying good common sense, are necessary to obtain accurate results.

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Leo Glanville—I definitely agree with you that the velocity readings obtained by an anemometer held in the hand are erratic and erroneous, due to the obstruction of the operator's body in the air stream. The smaller the cross section of an airway and the higher the velocity, the greater the error.

Occasionally where a grab air velocity reading is taken and accuracy is not required one center reading is taken and a correction factor of 0.8 is used.

On monthly routine ventilation surveys a 1-min traverse (12 positions of 5-sec each) is made and then immediately repeated, reversing the sequence of positions. The average of the two readings, after correction by calibration chart, is accepted as the mean velocity.

When an anemometer is used to determine fan efficiencies the same procedure is followed, with the exception that at least 20 positions of 5 sec each are used.

The clear section method is always used, with the anemometer held at least 5 ft in front of the operator.

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D. A. Harrington—As to the use of the anemometer, you are correct in calling attention to the gross carelessness in almost every phase of the use of the instrument in practically all mines and by practically all persons in all mines. I have realized for 30 yr or more that anemometer air measurements of the usual kind, by holding the instrument in the hand usually with the body in the air stream, are mere approximations and this is true to even a greater extent of the usual tape measuring of the cross sectional area.

These two *guesses* are multiplied together and the quantity thus secured is at best a not particularly close approximation as to the actual quantity available. However, generally this does not bother me inasmuch as very seldom, in my opinion, are extremely accurate measurements necessary except possibly when a ventilation survey is made to determine the size, type, and so on, of fan to be installed or the excess in power cost due to defective airways, overcasts, and other causes. Not 10 pct (probably much less than 5 pct) of those who use anemometers have the education to realize how to do accurate work with an anemometer or to obtain accurate results from the measurements or even to have anything like an adequate idea as to the significance of the measurements or the results (or expected results) obtained or obtainable from them.

In general anemometer work in mines, especially coal mines, is done largely to comply with some "*must*" law or regulation and when that is done responsibility ceases.

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Carl Lee—Commenting on your paper and its relation to ventilation prob-

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lesm in our coal mines, I believe it can be definitely stated that we have two separate and distinct problems. The first of these is that of the mine managers, face bosses, safety men, and others, who take readings of the volume of air on the various splits and at the faces.

It has long been standard practice that this is taken with a hand-held anemometer in almost any convenient place, without too much technical refinement for accuracy. It is reasonably certain to state that usually the volume of air as calculated from such measurements is higher than the actual volume if determined by more careful and possibly scientific measurements.

I believe that the majority of the coal companies, as represented by the officials thereof, will be willing to let this practice continue as is.

The second consideration in the measurement of air is that of accurately determining the volume of air in the various splits so as to coordinate with pressure surveys for the purpose of: (1) calculations of possible changes in the coursing of air to improve same, or (2) with respect to the performance of the existing fan or proposed replacement fan.

For the purpose of getting accurate readings, it certainly is desirable to use some refinements in measurement of air, so that the total cfm will reasonably check with the performance curves of fans as offered by the manufacturers. It is also important to have reasonably accurate volumetric reading in making estimates of recoursing of air for improvement.

However, with our company for example, it has been the writer's opinion that a pressure and volumetric survey of a mine rarely warrants the time required to calculate carefully all of the small corrections at every point, for air temperature, velocity head, and so on. Put in other words: at present, we consider it more important to get approximate surveys of all of our mines, rather than too refined tests on laboratory accuracy standard of only a few mines.

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RICHARD MAIZE—The rotating vane anemometer is a very practical instrument and is used by mine officials, safety engineers, and mine inspectors to find out if the fan is producing sufficient air to meet the requirements of the state law and whether the volume is sufficient at the working faces to dilute and render harmless all explosive and noxious gases. As a general rule, those using an anemometer for this purpose do not make the calibrated corrections, nor do they make several readings at different points in the cross-sectional area in order that an average mean velocity may be obtained.

In measuring the volume of air necessary to meet the requirements of the law, it is not necessary, in my opinion, to sectionalize the airway and hold the anemometer on a rod in each imaginary section. If the operator stands in the airway in such a position that the anemometer will be held in the approximate center of the flow of air, the operator's body will cause some turbulence in the air as it flows through the anemometer. However, for all practical purposes, this interference should make very little difference when all subsequent readings are made under like circumstances. If one is going to be so particular as to sectionalize the airway, he should then make some allowance for the area of the airway which is obstructed by his body, and deduct this from the cross section of the heading where the measurement is being taken.

When an operator is taking a reading in a regulator to determine the amount of air that is entering or leaving any particular section of the mine, no allowance is made for the "vena contracta." If the velocity of the air entering a regulator is high, the measurements are taken far enough away from it so that the readings are not affected by the high velocity of the air as it is rushing through the regulator. If there is a small volume of air entering the split, the operator usually holds the anemometer in the regulator, and in this case, the only obstruction encountered by the air as it passes through the regulator is that caused by the anemometer and the operator's arm.

Precautions, such as sectionalizing the airway for velocity measurements and the making of calibrated corrections, are all very necessary when determining the efficiency of a fan. The humidity of the air is another important factor and will greatly affect accuracy if not considered where large volumes of air are involved. In practice, it is possible that there be a difference of more than 2000 lb in the weight of the air delivered by the fan each minute, and a greater or less horsepower will be required to maintain the same fan speed, depending upon the relative humidity of the air.

A difference in temperature between the intake and return airways is another factor which tends to affect greatly the efficiency of a mine ventilating fan. It is not uncommon to find 20 pct less air entering a deep mine in the summer than that entering during the winter season, all factors being equal except the temperature.

My conclusions in reference to this problem are that the anemometer is not a badly abused engineering instrument. It will give the information one is seeking, whether for practical purposes, as in the normal operation of a mine where air measurements are made by the foremen as required by law, or when one is seeking technical information relative to fan efficiencies.

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A. S. RICHARDSON—I entirely agree with you that holding an anemometer in the hand is no good if the body is in the air stream. We make all our measurements by what you call the clear section traverse, using a number of fixed points central in equal areas, with equal periods of time at each area. However, we move from one point to another without stopping, and starting, and the traverse is made so that the anemometer can be started and stopped by the operator without it being necessary for him to move from his fixed position, out of the air stream. Also, I consider it to be essential that the reading be made near the center of an undisturbed straight run of at least 100 ft.

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G. E. MCELROY—I am opposed to the "clear-section," or downstream method of measurement because it is an awkward method and because I believe the air distribution is disturbed at a distance of 6 ft upstream from a man's body even though photographs of air-streams do not indicate that this would be the case. I have in mind a particular case where Pitot-tube velocity pressures were seriously affected by a 4-in. wide obstruction 4 ft downstream.

For ordinary mine air measurements I advocate holding the anemometer by hand in a way that offers minimum interference and considering the reading so secured as 5 pct high.

References

1. G. E. McElroy and A. S. Richardson: Resistance of Metal Mine Airways. U. S. Bur. of Mines *Bull.* 261 (1927) 103–110.

2. G. E. McElroy: Engineering Factors in the Ventilation of Metal Mines. U. S. Bur. of Mines *Bull.* 385 (1935) 6–14.

3. Pages 33–36 of ref. 1.

4. Callen and Smith: The Measurement of Air Quantities and Energy Losses in Mine Entries. Univ. of Ill., Engrg. Exp. Station, *Bull.* 158, Part 1, 14–16.

5. Pages 45–49 of ref. 4 and also *Bull.* 170, Part 2, 28–33.

6. Raymond Mancha: Ventilation. *Mech-annual* (1945) 182–183; and The Jeffrey Mfg. Co., *Catalog* 797 (1946) 40–41.

Discussion

B. F. TILLSON*—The manifold difficulties of accurate anemometry in irregular sections of mine passageways, the irregular distributions of velocities in cross sections of the same, and the disturbing influence of the observer upon the air flow, all indicate an undesirable inaccuracy of results obtainable by any standardized method of traversing the section by an anemometer.

It seems obvious that another, and simpler, method should be used to determine the volume of air flow in mine passages, namely:

1. At appropriate locations cement or calked framework rings should be installed permanently to equalize the irregularities of sectional contour and provide a place and means of attachment for a temporary cloth brattice which bears a rigid orifice.

2. The measurement of the velocity of air flow through the orifice may then be by anemometer or, preferably, by Pitot tube measurements of the differential pressures on both sides of the orifice in accordance with the standard practices available in engineering literature.†

The constants may be determined for various measuring positions in relation to the resulting "vena contracta."

3. The position of the person who makes the measurements is behind the brattice out of the air stream. The Pitot tube does not offer as disturbing an obstruction as the anemometer. A recording gauge may be employed to integrate fluctuations in air flow through that portion of the mine. No traverses are required because the reading may be at a single central point. An anemometer can be used with an orifice flow. The orifice will increase the air velocity at the measuring point, with correspondingly more accurate measurements where the normal air velocity through the passageway is low. Portable brattices might be devised with the cushioning rims which would seal against irregular rock surfaces where permanent rings were not available or feasible.

The development by the Ventilation Committee of standard procedures and devices for the orifice measurement of the flow of mine ventilating air might be a desirable project for this coming year.

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C. M. SMITH (author's reply)—Thank you for your discussion of my paper on underground anemometry. Your suggested method of measuring underground air flow is a novel one which might be applicable in some situations.

It should be tested along with other suggested methods in any investigation of this subject.

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G. E. MCELROY*—In spite of the adverse publicity that vane-anemometer methods of air measurement have had in the past and that contributed by the present paper, I endorse Mr. Krickovic's statement that anemometer traversing "has proved to be widely applicable, expeditious and simple" and add that available methods are accurate enough for the purposes for which they may be used.

The fact that the great majority of minor mine officials assess relative changes in rates of air flow by comparison of crude vane-anemometer measurements, known to average 20 to 30 pct high, has no important bearing on this subject, because state inspection standards were based originally on such methods of air measurement. Federal inspection standards are based on actual rates of flow as determined by traversing, and interest in traversing methods is rapidly increasing.

In considering traversing methods, three aspects are of major importance: (1) the absolute accuracy of calibrations; (2) the degree of interference with normal flow conditions introduced by traversing methods designed for accurate measurement by shaft-mounted instruments; and (3) the proper "method" factor to use for approximate measurements by hand-held instruments.

With respect to absolute accuracy of calibrations, we have always placed reliance on calibrations made by the National Bureau of Standards, with which manufacturers' calibrations have usually agreed very closely. It is therefore particularly disturbing to find[7] that calibrations made previous to June 1947 are presumably about 5 pct in error because of excessive registry caused by the thin flat plates on which anemometers were mounted for calibration. Velocities corrected for calibration have therefore averaged about 5 pct low in all probability. In this connection, it is interesting to note that an anemometer calibrated against Pitot-tube measurement by a single-point method in the Bureau of Mines experimental coal mine in 1923 indicated this same difference of about 5 pct and that the same instrument calibrated by a traversing method in a metal mine some months later indicated a difference in the same direction of about 4 pct. These results are reported by the Bureau of Mines.[8]

Regarding the degree of interference, or changes in velocity distribution, caused by the position of the observer's body in traversing operations, misconceptions seem to be especially prevalent, resulting in increasing advocacy of methods, such as the "clear section" method outlined in this paper, that cause just the type of interferences that they are designed to avoid. The degree of interference for any method may be gauged easily by a few experiments with a velocity-pressure gauge connected to a Pitot tube or with an indicating velocity meter such as the Velometer. In an experiment cited by McElroy and Richardson,[9] a decrease of 5 pct was noted at ten widths upstream from a 6-in. plank, whereas an observer's body at about the maximum practical distance of 6 ft downstream from the instrument is only about four widths away. In the Bureau of Standards paper previously mentioned, it is recommended that supports used in calibrations be at least 16 widths downstream. In practice, therefore, a downstream position of the observer is ruled out as far as accurate measurement is concerned.

Operation of the anemometer by rigid shaft support from a point outside the section is seldom practicable; however, accurate results can be obtained, with the anemometer rigidly attached to a short shaft and held at arm's length, by an observer advancing across the traversed section while he faces the opposite wall and stands sideways to the current, *provided* that he keeps the instrument at least 3 ft away from his body at all times and traverses the entire section with it. If the traverse can be started with the observer in a side recess, the entire section can be covered in one operation. Normally, it would be covered in two half-sections. The presence of the observer's body does not, as is commonly supposed, increase the average velocity throughout the remaining part of the section. Rather, the velocities 1 to 2 ft on either side of his body are increased, but the distribution of velocities throughout the rest of the cross section remains normal, and a traverse made as stated gives a true average velocity for normal-flow conditions.

Regarding the proper "method" factor for accounting for interference in the approximate methods of traversing with hand-held instruments, here again confusion prevails, for which the writer must assume some of the blame. Comparison of consecutive traverses made by shaft-held and hand-held 4-in. anemometers in field work after the tests reported by McElroy and Richardson[1] gave method factors

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[7] Galen B. Schubauer and Gerald H. Adams: Effect of Support on the Performance of Vane Anemometers. National Bureau of Standards Research Paper 1872, *Jnl of Research.* (April 1948), 40 275–280.

[1] Page 104 of ref. 1.
[9] Page 102 of ref. 1.

averaging about 0.90 in 40 to 50 sq ft metal-mine airways but averaged slightly higher—about 0.92—in a few 70 to 90 sq ft sections. Considering the effect to be one of relative size of airway, the figure was increased to 0.95 for coal mine airways and was so reported to an early class of Federal coal-mine inspectors and in answer to Mr. Smith's questionnaire. Apparently, the increase of factor from 0.90, as supported by experiment, to 0.95 based on opinion, was unwarranted. The figure of 0.90 is independent of the calibration, as both readings were corrected in each experiment before the ratio of 0.90 was determined.

Analyses of average results of the four most reliable groups of similar 4-in. anemometer traverses reported by Callan and Smith,[5] by comparison of calibration-corrected anemometer averages against Pitot-tube averages, give factors of 0.86, 0.85, 0.82, and 0.82 for Sections A, N_2, N_4, and Q_4 respectively. As the Bureau of Standards calibrations[7] then used were presumably about 5 pct high, these figures should be divided by 1.05 to obtain the corresponding method factors independent of calibration. These are 0.82, 0.81, 0.78, and 0.78, respectively.

Recent wind-tunnel tests by the Bureau of Standards[7] on the effect of supports on anemometer calibrations gave results averaging about 17 pct high for a 4-in. anemometer with two artificial-hand supports somewhat resembling those used in practice. The corresponding method factor, which does not, of course, take traversing procedure into account, is 1/1.17 or 0.85. Actually, the results of the tests on the 4-in. anemometer are somewhat out of line with comparable tests of the same series on 3 and 6-in. anemometers, and a possible factor of about 0.87 is indicated.

Because it is so sensitive to minor differences in the manner of holding the instrument, hand-held traversing should be used only for rough approximations. A suitable method factor for the exact method of holding can be determined preferably by consecutive traverses in a steady air current made alternately with the vane anemometer shaft-mounted and hand-held.

In my opinion, no elaborate program of tests of anemometer traversing methods is needed except such as may be required to convince those contrary-minded that no method should be used that involves placing the observer downstream of any traverse position or within 3 ft cross stream from any traverse position.

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C. M. Smith (author's reply)—It seems probable that the flow is so disturbed in all of the proposed methods of traversing as to lead to errors in the results; on the plus side in 2-position method (see Table 1), on the minus side in the multiple position and erratically on either side in the 1-position method. We will be in the dark as to the nature and extent of the errors until we test all proposed methods of anemometer traversing against some independent method such as Pitot tube traversing. I believe that underground anemometry is so important to health and safety in mining as to warrant the time and expense involved in putting it on a sound engineering basis.

Importance and Application of Piezoelectric Minerals

BY HUGH H. WAESCHE* Member AIME

Of all the military services, the Signal Corps is the most concerned with piezoelectric minerals because of its function as a supply service to the strategic and tactical military forces. Consequently this paper is written from the point of view of one associated with that organization. The Signal Corps is responsible for the research, development, and supply of communications, radar, and components to the using services of the Department of the Army and to some extent the other branches of the National Defense Department. Their work therefore includes the study of the sources, characteristics, and application of quartz and other piezoelectric materials. These materials have become a vital consideration in strategic planning and are essential for efficient tactical operation by all the Armed Forces. The Signal Corps at the beginning of World War II was responsible for both Army Ground and Air Force electronic equipment. Since that time this Army service organization has probably done more in the development of frequency control devices using piezoelectric materials than any other group.

The U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook of 1945, shows that during the four war years, 1942 through 1945, 9,598,410 lb of quartz crystal were imported for all uses and of this total, 5,168,000 lb were consumed to produce 78,320,000 crystal units for electronic application. Other government records confirm these data which conclusively show that approximately 53 pct of the crystalline quartz imported was consumed in the production of electronically applied quartz crystal units. It may be assumed that some effort was made to maintain a stockpile over demands for all purposes, and this would mean that the actual percentage of quartz used electronically was considerably over the 53 pct figure. These data only emphasize that electronic application of crystalline quartz was the greatest requirement, and perhaps the actual value in this application to national defense is many times greater in importance than is apparent on first inspection. Current electronic research and development programs of the Armed Forces are planned around the fundamental use of piezoelectric minerals for frequency control and this at present, at least, means quartz.

Definition and Early Development

The word piezoelectricity is formed from combination of the Greek word "piezein" meaning "to press," and "electricity." It is that property shown by numerous crystalline substances whereby electrical charges of equal and opposite value are produced on certain surfaces when the crystal is subjected to mechanical stress. It appears to be intimately associated with the better known property, pyroelectricity and in fact, the two may be manifestations of the same phenomenon. This property was discovered by Pierre and Jacques Curie in quartz, tourmaline, and other minerals in 1880 while studying the symmetry of crystals. The converse effect, that is, mechanical strain in the crystal when placed in an electrical field, was predicted by the French physicist, G. Lippman, in 1881, and verified by the Curies almost immediately. As has been the case with many discoveries of similar character in the basic sciences, not much attention was paid to this property for many years except as an entertaining curiosity. Between 1890 and 1892 a series of papers was published by W. Voigt in which the theoretical physical properties were put into mathematical form. The first practical application of piezoelectricity occurred during World War I when Professor P. Langevin of France used quartz mosaics to produce underwater sound waves. The same mosaics were used to pick up the sound reflections from submerged objects which were in turn, amplified by electronic means and used to determine the distances to such objects. This device was intended for use as a submarine detector but development was not completed in time for war service although it was used later for determining ocean depths. About the same time, A. M. Nicholson, of Bell Telephone Laboratories, developed microphones and phonograph pickups using Rochelle salt crystals. A major step in the application of piezoelectric quartz came in 1921, when Professor W. G. Cady, of Wesleyan University, showed that a radio oscillator could be controlled by a quartz crystal; from that date, this use of quartz has increased steadily, reaching its peak in World War II as is shown by the figures previously given. Essentially all American electronic equipment for communication, navigation, and radar, utilized quartz crystals for the exacting frequency control required.

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TP 2501 H. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before March 30, 1949. Manuscript received Feb. 27, 1948; revision, Oct. 6, 1948.

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Crystalline Minerals with Piezoelectric Properties

QUARTZ

Hundreds of piezoelectric crystalline materials are known, most of which are water soluble. Of these, quartz appears to be without a peer for electronic frequency control. Unfortunately, the quartz must be of superior quality. It must be free of mechanical flaws, essentially optically clear, free of both Brazil and Dauphiné twinning and must be, for average uses, over 100 g in weight. Because of these stringent requirements, raw quartz of the quality desired is of rare occurrence. In addition to quartz, several other naturally occurring crystalline materials are known to have the piezoelectric property and could perhaps be substituted for quartz in some applications. These

include tourmaline, nepheline and berlinite.

TOURMALINE

Tourmaline has certain desirable properties which would assure its widespread use if available in suitable quantity and quality; only light colored (noniron bearing) varieties are suitable for frequency control. Tourmaline of this type, of large size and in flawless crystals, is even more rare than suitable crystalline quartz. No known slice of tourmaline, cut with specific relations to the crystallographic axes, has the so-called zero-coefficient frequency-temperature characteristics of certain quartz "cuts";* it could not be used, therefore, in most of the precise frequency control applications that are normally required in electronics. However, tourmaline has a much higher frequency-thickness constant which makes it possible to attain fundamental frequencies higher than those of quartz. It was reported that the Germans produced during the war some tourmaline crystal units that had fundamental frequencies of about 400 megacycles per second. Tourmaline at this frequency is so thin—around 6 tenthousandths of an inch—that it is almost invisible. A slice of quartz having this frequency would be 4 tenthousandths of an inch thick when cut for highest frequency-thickness ratio. A thickness of this value is impractical; in fact quartz is not economically handled in current production if the thickness becomes much less than 4 thousandths of an inch for the preferred cuts.

NEPHELINE

Nepheline is assumed, on a theoretical basis, to be piezoelectric although its characteristics have not been measured, but qualitative tests have shown a positive piezoelectric effect. No known naturally-formed nepheline is suitable for piezoelectric use because the crystals are too imperfect, too small, or lack crystalline form as is true of quartz occurring in igneous rocks.

BERLINITE

The aluminum phosphate mineral, berlinite, is piezoelectric, based on theoretical and practical evidence. However, no known natural berlinite crystals are large enough for any practical use. The general crystalline structure of berlinite appears to be identical to that of quartz except the *c* axis of the unit cell is twice that of quartz. These four minerals are the only natural ones now considered actually or potentially applicable to piezoelectric use.

SYNTHETIC SUBSTANCES

A long list of artificial water-soluble crystalline piezoelectric substances has been investigated. Of these, only a few are of practical importance such as Rochelle salt ($KNaC_4H_4O_6 \cdot H_2O$), ADP (ammonium dihydrogen phosphate $[NH_4]_2H_2PO_4$) and recently, EDT (ethylene diamine tartrate $C_6H_{14}N_2O_6$). The latter was described by W. P. Mason,[1] of Bell Telephone Laboratories. Mason also suggests that DKT (di-potassium tartrate $K_2C_4H_4O_6 \cdot \frac{1}{2}H_2O$) may be a promising piezoelectric material. Of more than casual interest are some of the other tartrates and various borates, titanates, and sulphates. Although these crystalline substances have many and important applications, none have so far been useful for frequency control where any degree of stability or accuracy is required—and this remains, without question, the most important piezoelectric application.

Nature of Piezoelectric Effect

Piezoelectric theoretical considerations have been covered in great detail by W. G. Cady[2,3] and K. Van Dyke, of Wesleyan University and members of the Bell Telephone Laboratories, in publications of both book and periodical nature. The field by no means has been covered completely. However, there are certain fundamental assumptions that are generally accepted. Of the 32 possible crystal classes, 20 have the necessary properties to be piezoelectric. These classes are the ones of lower orders of symmetry. The piezoelectric effect depends upon the dipole moment of the molecule, *not* the symmetry of the crystal class. The number of piezoelectric constants in a given crystal *does* depend upon its symmetry and class. The rhombohedral-trapezohedral class of quartz is definitely in this category. The piezoelectric effect is explained by the assumption that, when a stress is applied to a crystal having no center of symmetry, the centers of gravity of the positive and negative electrical charges in the molecules are displaced in opposite directions. The displacement is proportional to the pressure, and the total charge for a given crystal is the sum of the molecular charges. In a crystal having a center of symmetry, as in the extreme case of the isometric normal class, no displacement of this nature occurs because all internal displacement conditions are equal and opposite. Conditions for resultant piezoelectric charges on a crystal apply only if it is untwinned. If the crystal is twinned, the charges produced in one twin will oppose those in the other twin, thereby reducing the overall effect. If the two portions of the twin are equal, the net charge for the whole crystal will be zero. The two types of twinning in quartz most frequently encountered are Dauphiné, known in piezoelectric work as electrical or 180° twinning, and Brazil law or optical twinning. The electrical twinning is an 180° reversal of the crystalline structure with the *c* crystallographic axis, the twinning axis, both portions having the same handness, that is, right or left in any one crystal. In the case of the Brazil law, or optical twinning, the *a* face ($11\bar{2}0$ trigonal prism face) is the twinning plane producing both right and left handed forms in the same crystal. Neither type of twinning is permissible in crystals used for frequency control purposes and of the two, small amounts of optical twinning appear to be the less detrimental. Every effort is made to prevent the use of quartz having either type of twinning in the production of crystal units. Optical twinning is readily recognized in polarized light, but electrical twinning usually can be determined only by etching the surfaces to be observed with hydrofluoric acid.

SPECIFICATIONS

At least a general knowledge of crystallography is necessary in order to produce piezoelectric working units. The crystalline elements of such units must have been carefully oriented in relation to the crystallographic structure before being cut from the crystal. It is this crystallographic orientation of the finished plate that determines certain of the most desirable per-

* The term "cut" in piezoelectric terminology refers to the angular relations between the surfaces of the slice, wafer, or bar of oscillator or filter quartz and the crystallographic axes of the crystal from which obtained.

[1] References are at the end of the paper.

formance characteristics of the unit of which the temperature frequency characteristics are the most important. The latest frequency controlling element specifications for quartz require orientations which must be accurate within at least 3 min of arc. In many cases linear dimensions are of the order of a few ten thousandths of an inch, and the frequency determining dimensions are so exacting that they are measured by frequency change rather than by the linear differences which would be of the order of subdivisions of millionths of an inch; removal of one molecular layer from the surface of a high frequency quartz oscillator plate could, under some conditions, move the frequency out of allowed tolerances. The simple appearance of a small plate of quartz ½ by ½ by 14/1000 in. belies the development, care, precision, and human energy that have gone into its production. Diamond saws, optical and X ray orientation apparatus, lapping machinery, temperature and electronic measuring and testing equipment are only a few of the items required and used in its fabrication.

Quartz

Quartz is discussed at greater length than other materials because of the unique position it occupies in the piezoelectric field. Quartz is outstanding in mechanical durability, elastic qualities that give it a very high Q (defined by Cady as ratio of stored to dissipated energy), and an atomic combination in the molecule that results in different physical properties in different directions. Because of the last factor, positive and negative temperature-frequency coefficients are available in a crystal, thereby permitting the production of so-called zero coefficient units. A zero coefficient cut oscillator plate is crystallographically oriented so that normally positive and negative temperature frequency characteristics are cancelled partially to produce a zero frequency change for a limited temperature change. This last is a property, for instance, that tourmaline lacks.

PRODUCTION AND SOURCES

At the outbreak of World War II only a handful of people in the United States had had any experience in the knowledge of or production of piezoelectric crystal units. Through a program of expansion and education sponsored by the Signal Corps and other Government agencies, the number of active manufacturers reached 150. Along with this increase in number, there was a great increase in production, and efficiency became high enough to double the yield per pound of raw quartz.

Most of the raw quartz consumed in frequency control unit production during the four war years was obtained from Brazil. Other material from Arkansas, California, and scattered deposits elsewhere in the United States was used. Some very small amounts of inferior quartz were obtained from Guatemala. It was reported that Russia had ample supplies and that sizeable deposits existed in Madagascar. The mining in Brazil was primitive and difficult and the transportation, over long, undeveloped interior distances to the coast was slow and not too reliable.

In addition to quartz, other strategic materials were required in the fabrication or composition of frequency control elements. These include industrial diamonds for sawing and grinding, silicon carbide or corundum for lapping and polishing, fluorine for etching, as well as minor quantities of beryllium-copper for springs, nickel, chromium and tin for plating, and lead, zinc, copper and silver in various other functions.

MILITARY USES

As previously stated, piezoelectric minerals from a military viewpoint are far more important than is normally indicated. Usually the importance of major equipment is widely publicized, but seldom that of the component parts. Piezoelectric minerals were given relatively little consideration before the war. It is possible to build and design certain electronic equipment that will work without quartz crystal, but the efficiency of both equipment and personnel become greatly reduced. Quick, reliable frequency change and clear channel operation require the use of crystals. No other means of attaining the same conditions are known, which explains why all military services persist in using piezoelectric frequency control devices in electronic equipment. In 1942, it was soon discovered that without a quartz crystal a radio communication set would not work, without the communication set a tank unit could not operate, and worse than that, a plane could not fly; a genuine potential case of "for want of a nail, a war was lost." Piezoelectric quartz really came into its own when bombers and fighters were grounded for lack of crystal units. It was the heart of radio communication and much of the navigation equipment.

Ground Forces

The U. S. Army Ground Forces need piezoelectric crystals principally as a frequency control element in communications equipment. Some of these required as many as 900 crystal units, although that was not the usual rule; however, 120 per equipment were not unusual. Quartz crystals were used in fixed stations, vehicular radios, walkie talkies, handie talkies, telephone and teletype equipment, facsimile equiqment, meteorological equipment; in tanks, in jeeps, on horseback, in rucksacks, in fact, in about every place a soldier or a machine of ground warfare could or would go. In nearly all cases at least two crystals were available for use per equipment at a time; one for transmitting and one for receiving. Quartz crystals were required for radar, but the quantity was insignificant compared with that needed for communication equipment. Field frequency meters and frequency standards required quartz crystals. In addition to quartz, artificial crystals of Rochelle salt and ammonium dihydrogen phosphate were used for microphones, phonograph pickups, phonograph recorders and head phones.

Air Forces

The Air Forces used many of the Ground Force equipments although to a lesser extent. The now famous "handie talkies" were a major Ground Force equipment so used. In addition, the Air Forces had several specialized requirements—all dependent on quartz crystal for frequency control. These applications were in VHF (very high frequency) command sets, requiring the bulk of the Air Force quartz crystal units, navigation equipment, and sea rescue equipment. The Air Forces procured a very large quantity of crystal units for the British Royal Air Force. The quantity production radio communication set known as the SCR-522, in every RAF and American fighter or bomber, required eight crystal units for designed operation, four for the transmitter and four for

the receiver. In addition, it was necessary to stock at least as many spares per set as well as have on hand the frequencies for over 100 channels. Use of the SCR-522 alone required the production of around twenty million crystal units.

Navy and Coast Guard

The Navy and Coast Guard demand for quartz crystals was relatively low at the outbreak of the war but increased rapidly so that by the end of the conflict they were procuring large quantities of the Air Force type of crystals plus others peculiar to their own requirements. One of the most important Navy-Coast Guard applications was in the now famous Loran equipment. This revolutionary ultra-accurate navigational aid depended on a very special type of quartz crystal unit for its phenomenal performance. The units were essentially hand tailored for each equipment and required a perfect piece of quartz crystal of medium or larger size. The Navy used large quantities of piezoelectric ammonium dihydrogen phosphate (ADP) in sonar equipment for underwater submarine detection, depth sounding, obstacle locating, and similar applications. The principle is the same as that originally developed by Langevin. Quartz, however, is no longer used since artificial crystals in this particular application are preferred because of their much greater piezoelectric effect and the frequency accuracy of frequency control applications is not required.

NONMILITARY USES

The National Bureau of Standards in Washington depends on quartz crystals for the standard frequencies that are broadcast continuously by radio. The crystals used are similar to those in the Loran equipment previously referred to except that temperature control is more rigorously maintained. This very interesting and important application of crystalline quartz is perhaps its most exacting and conclusively demonstrates the superiority of quartz in this service over any other known material. Several of the crystals operate continuously as checks against erratic behavior; however, only one is "on the air" at a time. The transmitted frequencies are continuously checked against Naval Observatory time and are guaranteed accurate to 1 part in 50,000,000 although it is believed the accuracy may be much better. This means the piece of quartz actually mechanically vibrating 100,000 times per second 24 hr per day furnishes time and frequency which are so accurate that it is now questionable if the man-made measurements of the solar system are accurate enough for confirmation purposes. It is thought possible that the quartz beat is more regular than the solar cycle, and consequently the point may have been reached where it would be difficult to say whether the apparent variations are those of solar origin or of the quartz. No tuning fork could equal this performance, nor for that matter could any other known currently available system of frequency control. The National Bureau of Standards explores all possible means and materials to this end and so far has found no substitute. The signals transmitted by the Bureau of Standards Station, WWV, are used as the standard for all the Armed Forces, commercial organizations, research laboratories, and by similar groups in foreign countries. It would be difficult to appraise the actual value in everyday living for mankind of this frequency source—depending on a piezoelectric mineral. All radio channels, broadcast and otherwise, depend on quartz crystals for accurate frequency control. It is the quartz crystal in the transmitter that makes it possible for broadcast stations to be within a few cycles of exactly the same frequency day in and day out. The accurate Loran and other navigational equipments, depending locally on quartz, in turn depend on the frequencies from the Bureau of Standards. The Bureau of Standards broadcasts the standard signals on 5, 10, 15, 20 megacycles and other frequencies.

In addition to radio, teletype, telephone, and other wire services depend on quartz or the new ethylene diamine tartrate (EDT) crystals in the transmission of numerous services over a single wire or cable. In this use, the piezoelectric material acts as a gate or filter allowing only the desired signal of the correct frequency to get through. Another widely used application of quartz is in the control of power frequencies. It is this use that makes power operated electric clocks maintain their time accuracy within a matter of seconds. This use is otherwise important to both the power suppliers and users in that meter readings are accurate and uniform. Poor regulation means the watt-hour meter runs too fast or too slow depending on the frequency. All these frequencies revert back to the National Bureau of Standards for reference and calibration. Quartz crystals are used frequently in radio communications receivers. In this case they are not detectors as was the old galena detector but instead act as filters limiting the band width of the received signal and thereby making it possible to receive more signals with less interference.

A growing use of piezoelectric materials is in the field of supersonics. In this case the piezoelectric material is excited mechanically by an electric field. The mechanically vibrating crystal transmits its energy to an adjacent or surrounding material setting up supersonic waves which travel through the medium. This is useful in homogenizing milk, making emulsions of oil in water, settling smoke, fog, or dust, and similar operations. The same principle has recently been applied to detecting defective railroad engines and car wheels. The list of uses in general, grows daily.

Toward the end of the war, many radio manufacturers considered the use of quartz crystals in home radio receivers. The idea appeared to have merit, especially for accurate push-button tuning. However, the competitive market and the additional expense have prevented such application except under special circumstances and in more expensive models. At the higher frequencies now being used more and more for frequency modulation, television and citizens radio, this application may become mandatory.

Tourmaline

Tourmaline has various excellent properties but enjoys only limited use because of the previously mentioned rare occurrence in suitable quality. It has one property of special value, lacking in quartz. It reacts to hydrostatic pressures and therefore is much in demand for blast pressure gauges. Tourmaline so far has had little application in frequency control. No other natural minerals are known to have had any piezoelectric application. Since the characteristics of nepheline have not been measured completely, its performance characteristics as yet are unknown.

Quartz Supply Program

The greatest single, deterring factor in the more widespread application of quartz crystals is the supply of raw material. As long as the source material is available and the supply lines are open, the situation may not be too critical. National defense considerations do not permit any question of supply to exist without exploring other possibilities. A situation of this nature is of prime importance to the Signal Corps which must have quartz or a suitable substitute to fulfill its mission. For this reason the Signal Corps Engineering Laboratories at Fort Monmouth, N. J., have launched a program designed to promote public interest in locating additional domestic sources (continental) for piezoelectric grade quartz and other piezoelectric minerals. This program is not intended to suggest that there are large commercial possibilities involved or that this Government Agency is anticipating large scale procurement, although it is certainly believed likely that the use of piezoelectric grade quartz would increase if larger domestic sources were developed. This program is purely for national defense consideration and is intended to be coordinated with the other concerned government organizations such as the Geological Survey and the Bureau of Mines. If commercial possibilities are opened up as a part of this program, the government can feel doubly paid for its efforts. In any case, it may be assumed that piezoelectric mineral applications will increase rather than decrease in the future and that the increase in importance both commercially and militarily will increase in proportion. Availability of larger domestic sources would undoubtedly accelerate this progressive development.

Development of Synthetics

As indicated in the January 1948 issue of *Mining and Metallurgy*, the Signal Corps is not only interested in natural piezoelectric mineral sources but it is also involved in extensive sponsorship of synthesis of piezoelectric materials. Two contracts are in effect for the synthesis of quartz. Initially this work followed the leads of Spezia and Nachen—the latter active in the efforts of Germany to produce synthetic quartz during the war. Nachen claimed laboratory production of synthetic quartz and claimed that his method would be feasible for large scale production. The investigators in this country have found it necessary to use modifications of his method and new approaches. However, all have synthesized quartz in the laboratory to a varying degree, and results so far have certainly justified the effort. The work on quartz is being done under the direction of Professor A. C. Swinnerton at Antioch College, Yellow Springs, Ohio, and under the direction of Dr. D. R. Hale at the Brush Development Co. in Cleveland, Ohio. The Naval Research Laboratories in Washington, D. C., have contributed heavily to the overall synthetic program, including quartz, in their own laboratory. In addition, at least one commercial organization is successfully synthesizing quartz independently. Tourmaline crystals of a lithium type, low in iron, but of small size have been synthesized at Baird Associates, of Cambridge, Mass., under direction of C. Frondel, of Harvard, with a Signal Corps contract. Under similar contracts, The Edward Washken Laboratory, of Cambridge, Mass., has synthesized small nepheline crystals and the Geology Department at the University of Minnesota has synthesized crystals of aluminum phosphate which may be berlinite, under the direction of Professor J. W. Gruner. Fairly large crystals of the last referenced material have been grown at the Signal Corps Engineering Laboratories, Fort Monmouth, N. J. Brush Development Co. has been growing readily, large size water-soluble crystals which are important because of potential piezoelectric use other than frequency control. In addition to the practical aspects outlined, from the academic viewpoint, the success of these projects is believed assured by contributing to the overall store of knowledge regarding crystal growth and its application to the study of ore deposits. That many of the natural minerals may have been formed at much lower temperatures than previously accepted, seems possible. As the projects proceed and more information is gained, the technical details will become available through publication and technical meetings.

Organization for Future Development

The Signal Corps Engineering Laboratories have technical personnel that accomplish or sponsor through outside contracts, the technical research and development necessary for making available the myriad components and equipment for satisfactory military communications, radar, navigation, meteorological, and associated functions. In addition to piezoelectric minerals, manganese for batteries, and mica for condensers, are outstanding among many minerals with which these laboratories are concerned. The Frequency Control Branch of Squier Signal Laboratory is the organization of these Service Laboratories responsible for development of new and improved quartz or other piezoelectric frequency control units. Geologists participate actively in the direction of planning and functioning of this Branch.

It has been suggested that the recently publicized EDT crystals would relieve the need for raw quartz. Nothing in the published literature or from other sources indicates that this is the case. Quartz remains the principal means of frequency control without any immediate hint of a real competitor. EDT crystals can and will supplant quartz in telephone resonator service thereby relieving the quartz supply problem to a small extent. This definitely extols the quality and desirability of quartz but does not correct the supply problem, especially in times of national emergency. Domestic sources of piezoelectric minerals are still the best insurance for the future coupled with a program of successful synthesis of piezoelectric frequency control crystals. Recent public announcements by both Bell Telephone Laboratories and the Signal Corps indicate successful quartz synthesis on a laboratory scale exceeding any previously reported.

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Beneficiation of Industrial Minerals by Heavy-media Separation

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THE sink-float methods designated by heavy-media separation processes were pioneered by C. Erb Weunsch for the treatment of base metal ores as an improvement over jigs. The work of Weunsch was further developed by Victor Rakowsky and The American Zinc, Lead and Smelting Co.

Early in the development of the processes, the inherent unsuitability of galena as the solid constituent of the medium was recognized and ferrous media amenable to magnetic recovery and control were developed.

The high efficiency and low cost of magnetic recovery and cleaning of ferrous media regardless of particle size, slime contamination, or surfacial oxidation had led to the adoption of ferrous media by all of the sink-float plants operating under the heavy-media separation processes patents controlled by American Zinc, Lead and Smelting Co. Approximately 2,000,000 tons of base metal and nonmetallic minerals are treated each month by these methods.

Heavy-media separation processes are a modern practical and economical adaptation of the well-known laboratory procedure for separating a mixture of two solids by immersing the mixture in a liquid having a specific gravity intermediate the specific gravities of two solids. The lighter solid floats while the heavier sinks. This method of separation has been attempted on a commercial scale, but the high loss and high cost of the organic liquids halted the development of the process.

Many attempts have been made to simulate a heavy liquid by using a suspension of a finely divided solid in water. If the solid phase of the suspension is ground fine enough, the suspension can be made stable or so slow settling that a substantially uniform specific gravity can be maintained from top to bottom of the bath. However, any material separated by such methods will inevitably be contaminated by some slime which will eventually accumulate in the bath and cause a viscous medium at the expense of separating efficiency. Therefore, it is necessary to provide means for continually cleaning a portion of the medium to eliminate slime at the same rate at which it is introduced to the medium. The problem of efficiently cleaning the medium limits the minimum grain size of the solid of the suspension in the case of the Chance sand process for cleaning coal, because decantation is the only cleaning method available. If the sand is too fine, it will be lost along with the slime. Therefore, coarse sand must be used, and to maintain a semblance of a uniform suspension, it is necessary to use strong rising water currents. The combination results in a separation based more on hindered settling classification than on sink-float principles.

As previously mentioned, galena was used as the solid constituent of the medium during the early stages of the development work. The high specific gravity of galena made it suitable for the preparation of medium for high specific gravity separations. Galena can be cleaned by either decantation or by froth flotation. As with sand, decantation limits the minimum particle size of the media that can be cleaned without excessive loss. Froth flotation for cleaning galena medium has been used, but the problem of floating fine galena that has been exposed to extensive oxidation is well known to be a most difficult one. Last year the largest heavy-media plant in the world, and the second plant to be installed, converted from galena medium to ferrous medium despite the fact that the ore contains galena which can be used as medium. The change to ferrous medium has been beneficial in many ways. Today all the heavy-media plants have been converted from galena to ferrous media.

Unquestionably, ferrous media have the widest application of any media developed, for the following reasons:

1. Ease of recovery and cleaning by magnetic means. Particle size or surface condition not a factor.
2. Low consumption per ton of ore treated.
3. Resistance to abrasion.
4. Widest range of media densities, including higher workable densities (1.25 to 3.4) than have been found possible with nonferrous media.
5. Space required for recovery and cleaning of ferrous media is considerably less than that for nonferrous media.
6. Ferrous media require lower capital investment and operating costs for media recovery and cleaning.

Advantages of Heavy-media Separation Processes

Heavy-media separation processes offer the following positive advantages, amply demonstrated on a wide variety

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of ores—nonmetallic as well as metallic, and coals.

1. Ability to make sharp separations at any predetermined specific gravity ranging from 1.25 to 3.4; and continuously maintain this preselected specific gravity within plus or minus 0.01. Efficient cleaning methods eliminate viscosity problems.

2. The specific gravity of the separating medium can be changed at any time, and within a few minutes, when necessary to meet changing characteristics of feed.

3. Ability to remove sink, or refuse, continuously.

4. Ability to treat full-size range material without presizing.

5. Heavy-media separation plants can be started and shut down without loss of values or operating efficiency.

6. The medium used for separation is relatively low cost and losses incident to the operation are negligible (0.2 to 0.8 lb per ton of feed). Since the medium can be recovered from the separated products almost completely, loss of values and medium due to the inefficient presizing caused by variable moisture in the feed is no longer a serious consideration.

7. Low operating and maintenance costs.

8. Separatory units have large capacity and occupy relatively small space.

9. Capital cost low in comparison with installation of competitive processes of equal capacity.

Scope of Heavy-media Separation Processes

GENERAL FIELD OF APPLICATION

In general, it may be stated that heavy-media separation processes will treat any ore in which the valuable mineral constituents have an appreciable difference in specific gravity from the worthless gangue. This difference in specific gravity can be less than that required for efficient separations by jigging or tabling.

In general three types of ore are amenable to heavy-media separation processes:

1. Ores whose valuable constituents are liberated from unwanted mineral by coarse crushing.

2. Ores containing valuable minerals in the form of lenses or veins separated from each other by barren gangue.

3. Ores containing barren gangue which can be rejected after coarse crushing.

The heavy-media separation processes are capable of performing three main functions.

1. Rejection of a waste product leaving an enriched product for further concentration by other methods after reduction in size.

2. Production of a finished concentrate and a rejectable waste in one operation.

3. Production of a finished concentrate, and a low-grade reject for additional treatment.

Heavy-media separation processes have a wide field of usefulness as preconcentration methods for removing gangue, at low cost, after coarse crushing. Therefore, they offer a cheap and effective means for making ore out of sub-ore, waste dumps and tailings, by concentrating the valuable constituents into a smaller product of sufficiently high grade to warrant treatment by more expensive methods such as flotation or cyanidation.

The application of heavy-media separation processes is related closely to the type of mining practiced or contemplated. It is, therefore, necessary to study the geological structure of the deposit to determine whether high cost selective mining methods may be eliminated through use of these processes to reject waste rock mined over greater widths. Similarly, by locating the heavy-media plant underground a hoisting bottle neck may be eliminated, at far less expenditure of time and money than would be required to sink and equip a new shaft. Installation underground, moreover, provides a waste product for back filling at no additional cost.

Of particular importance to established operations are the opportunities through heavy-media separation processes for increased profits by lowering of costs, for increases in production, and for reduction in overall labor requirements per ton of metal or mineral produced. An existing flotation mill, for instance, may greatly increase its metal output through increasing mill heads by installing heavy-media separation before fine grinding.

RANGE OF SIZES AMENABLE TO HEAVY-MEDIA SEPARATION

In general, it may be stated that heavy-media separation processes are applicable to the separation of sizes down to as small as 35 or 48 mesh. Although in some instances it is feasible to handle run-of-mine ore without presizing, the efficiency of separation drops off on sizes below 48 mesh.

For the treatment of sizes up to 3¼ in. a separatory cone may be used. Other apparatus is available for treatment of sizes larger than 3¼ in.

Regardless of the type of separatory vessel used, the underlying principles of heavy-media separation processes remain unchanged, although the flowsheet may vary. In this connection, as will be explained later, the treatment of full size range material, including sizes below 10 mesh, necessitates the use of more equipment than is required for handling sizes down to 10 mesh only.

RANGE OF SEPARATING GRAVITIES OBTAINABLE

Highly efficient separations have been made on coal at specific gravities as low as 1.25, using magnetite medium. With this medium it is possible to make highly effective separations up to 2.20 sp gr. For the range 2.20 to 2.90, mixtures of magnetite and ferrosilicon are satisfactory. Above 2.85, ferrosilicon alone is used and separations at 3.40 sp gr have been made commercially.

CHARACTERISTICS OF MAGNETIC MEDIA

Magnetite (Fe_4O_4) is a naturally occurring mineral found in abundance in many countries and is mined as an iron ore.

Ferrosilicon (Fe 85 pct, Si 15 pct) is a furnace product obtainable from various suppliers in several grades of suitable fineness.

Operations of Heavy-media Separation Processes

The essential steps in heavy-media separation processes are.

1. Preparation of the feed.
2. Heavy-media separation.
3. Removal of medium from the separated products.
4. Reclamation and cleaning of the medium for reuse.

PREPARATION OF FEED

Primary slimes, and fines which are not amenable to sink-and-float separation, are objectionable because they dilute the medium and increase its viscosity. Such fines and slimes should

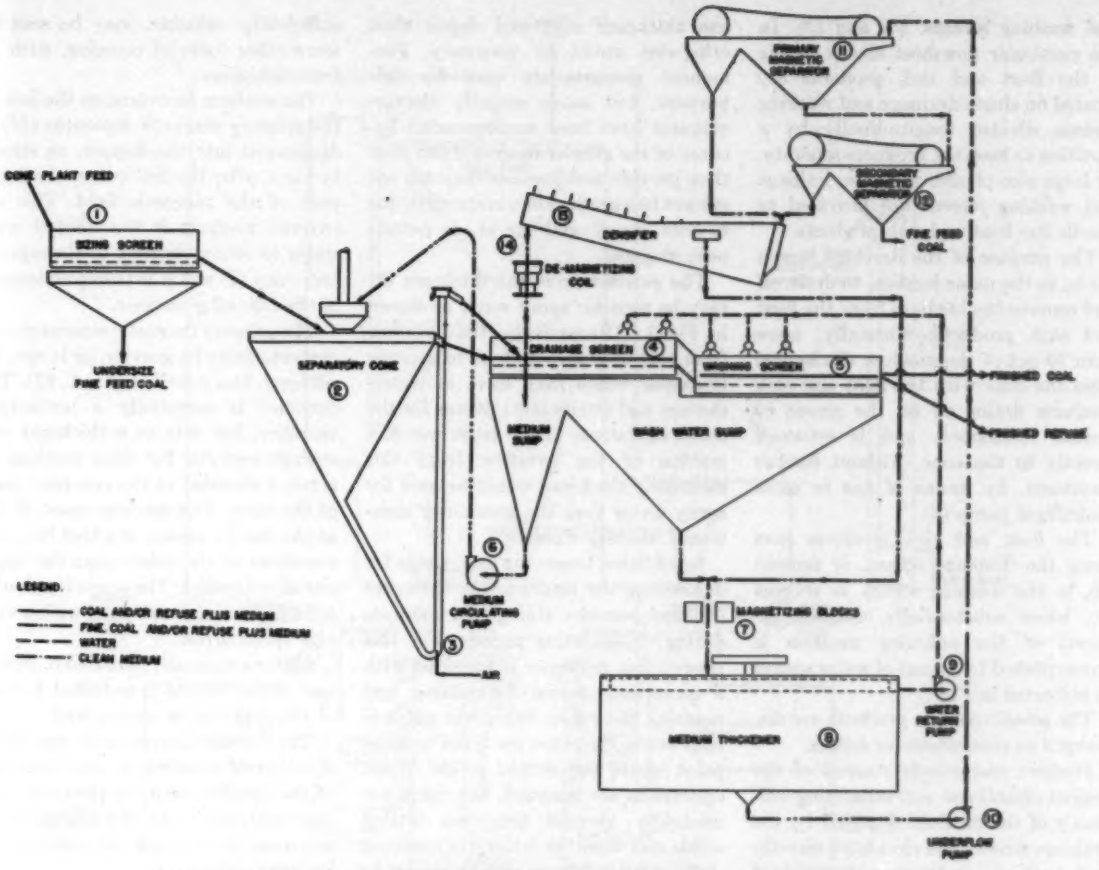

FIG 1—Standard flowsheet for sizes coarser than 10 mesh, using ferrous media.

be removed as completely as possible prior to heavy-media separation.

Fine granular or colloidal particles having a lower specific gravity than that of the solid constituent of the medium have two definite disadvantages:

1. They lower the specific gravity of the medium.

2. They reduce the separating efficiency of the medium because of increased viscosity.

The harmful effect of slime can be reduced to a great extent by the use of efficient methods for cleaning the medium. The development of ferrous media and magnetic recovery have eliminated the need for complete slime removal before treatment because of the efficiency of magnetic concentration. At one operation using ferrosilicon, the ore treated is high in slime content. The only equipment employed for 125 tons per hour is one 4 by 12 ft screen fitted with washing sprays for the first 6 ft only. This treatment only partly deslimes the ore, in fact a substantial quantity of clay balls is sent with the ore to the heavy-media cone. With other types of sink-float processes, the treatment of such slimey ore tends to result in medium contamination and high viscosity, but with ferrous media and magnetic cleaning, the slime is rejected from the medium as rapidly as it is introduced and a satisfactory separating medium is maintained without difficulty.

A clearer understanding of the basic principles of separation, and the method of recovery and cleaning of media can best be obtained by referring to the flowsheet shown in Fig 1. This flowsheet is the one most commonly used for treatment of sizes coarser than 10 mesh, using ferrous media.

For the treatment of sizes finer than 10 mesh, a modified flowsheet is used wherein separate medium cleaning circuits are employed for selectively separating and recovering medium from fine float and fine sink. This innovation is discussed later.

Referring to Fig 1, it will be noted that the finer sizes are removed from the feed by the primary washing screen (*1*) before it enters the separatory cone (*2*).

HEAVY-MEDIA SEPARATION

In the separatory cone (*2*) which is filled with ferrous medium of preselected gravity, the low gravity minerals float on the surface of the medium and are removed by overflowing a weir opposite the point of entry of feed. The heavier gravity minerals sinking through the medium are removed continuously from the cone by means of an "air lift" (*3*). The latter, as will be noted, is, roughly, a *J*-shaped pipe of suitable size connected to the bottom of the cone. Jets of compressed air introduced at the bottom of the vertical section of this air lift serve to elevate the sink particles in an effective and economical manner.

REMOVAL OF MEDIUM FROM SEPARATION PRODUCTS

The float and sink products discharged from the cone go to drainage

and washing screens, (*4*) and (*5*). In the particular flowsheet shown in Fig 1, the float and sink products are treated on single drainage and washing screens divided longitudinally by a partition to keep the products separate. In large size plants, separate drainage and washing screens are provided to handle the float and sink products.

The purpose of the drainage screen (*4*) is, as the name implies, to drain off and remove the medium from the float and sink products. Normally, more than 90 pct of the medium discharged from the cone with the float and sink products drains off on the screen or screens mentioned, and is returned directly to the cone, without further treatment, by means of one or more centrifugal pump (*6*).

The float and sink products pass along the drainage screen, or screens (*4*), to the washing screen, or screens (*5*), where substantially complete removal of the adhering medium is accomplished by means of water sprays as indicated in Fig 1.

The screen oversize products are discharged as concentrate or tailing.

Positive and simple control of the desired cleanliness and separating efficiency of the medium removed by the drainage screens and circulated directly back to the separatory cone is provided by a readily adjustable diverting chute underneath the drainage and washing screens (*4*) and (*5*). By means of this chute, more or less medium may be diverted from the drainage hopper to the washing hopper and thence to the cleaning circuit.

RECLAMATION AND CLEANING OF MEDIUM FOR RE-USE

The medium removed by washing is too dilute and, in many instances, too contaminated with fine impurities to permit of its being returned directly to the separatory vessel. Accordingly it is treated in a novel manner as follows.

The undersize from the washing screen (*5*) first flows by gravity, or is pumped, to a medium reclamation thickener (*8*). Just before it enters the thickener the diluted medium passes between a set of magnetizing blocks (*7*). These latter serve to change the charge on the discrete ferrosilicon or magnetite particles whereby they become mutually attracted and flocculate. The net result of this is faster settling of the particles in the thickener with consequent advantage of requiring less thickener area and depth than otherwise would be necessary. Permanent magnets are used for this purpose, but more recently electromagnets have been recommended because of the greater magnetic flux that they provide and because they are not subject to a gradual loss in strength due to heat, shock, and age as are permanent magnets.

The overflow from the thickener (*8*) may be used for spray water as shown in Fig 1. Alternatively, the overflow from this unit may be sent to another thickener which may serve as water-storage and clarification means for the entire operation. In the latter event, a portion of the overflow from this secondary thickener would be used for spray water over the previously mentioned washing screen (*5*).

In addition to serving as a means for dewatering the medium, the thickener (*8*) also provides storage for medium during off-operating periods. For this reason, this thickener is provided with a motorized device for raising and lowering the rakes. When the plant is shut down, the rakes are lifted to some point above the settled solids. When operations are resumed, the rakes are gradually lowered into the settled solids and then the latter are rendered sufficiently mobile so that they may be removed eventually by means of a centrifugal pump (*10*) and thereby sent to the cleaning circuit comprising at least two magnetic separators, (*11*) and (*12*).

When it is desired to increase the specific gravity of the medium in the separatory cone during operation in order to meet some change in characteristics of feed, an extra amount of medium can readily be introduced into the circuit by lowering the rakes in the thickener.

The magnetic cleaning circuit, as shown in Fig 1, comprises a primary (*11*) and a secondary (*12*) Crockett-type magnetic separator. These separators are of the belt type, the magnet assembly being mounted just above the lower section of the belt. Feed is added under the belt as shown and the fines, not immediately picked up by the action of the magnets and carried by the rubber belt, are dropped and eliminated through the hopper, as shown. This tailing, or reject, goes by gravity to the secondary magnetic separator (*12*) for additional treatment in order to recover any traces of medium not picked up in the primary separator. The tailing from the secondary separator (*12*) goes to waste; or if sufficiently valuable, may be sent to some other form of cleaning, such as froth flotation.

The medium recovered on the belt of the primary magnetic separator (*11*) is discharged into the hopper, as shown in Fig 1, after the belt passes the influence of the magnetic field. This recovered medium is too diluted with water to return directly to the separatory cone (*2*) and it is therefore treated in the following manner.

The primary magnetic separator concentrate flows by gravity, or it may be pumped, to a densifier (Fig 1, *13*). The densifier is essentially a screw-type classifier, but acts as a thickener and storage reservoir for clean medium. It is not a classifier in the accepted sense of the term. The machine must be fed at the end by means of a feed box, and overflows at the sides—just the opposite of a classifier. The screw is a double helix flight and is equipped with a variable speed drive.

Either a manually operated or motorized lifting device is provided to raise or lower the screw as required.

The densifier performs the important function of assisting in the regulation of the specific gravity of the medium in the separatory cone in addition to dewatering the medium recovered by the magnetic separators.

The medium removed by the secondary magnetic separator (*12*) may join the flow of medium recovered by the primary separator (*11*). Alternatively, it may join the overflow of the densifier (*13*) which returns to the thickener (*8*).

The screw discharge of the densifier returns by gravity to the separatory cone (*2*) via the drainage hopper and medium return pump (*6*). Before it reaches the drainage hopper, however, it passes through an alternating current demagnetizing coil (*14*). This is an essential step in the heavy-media separation flowsheet. The dispersing effect imparted to the particles of medium by the action of the demagnetizing coils gives fluidity to the medium in the separatory cone without which satisfactory operation could not be maintained.

As previously stated, the densifier (*13*) provides a means for ready adjustment of the specific gravity of the medium in the separatory cone. The medium discharged by the screw is of considerably higher specific gravity than the medium in the cone. Therefore, water may be added to the medium returned to the cone by the pump (*6*). Ordinarily, any required

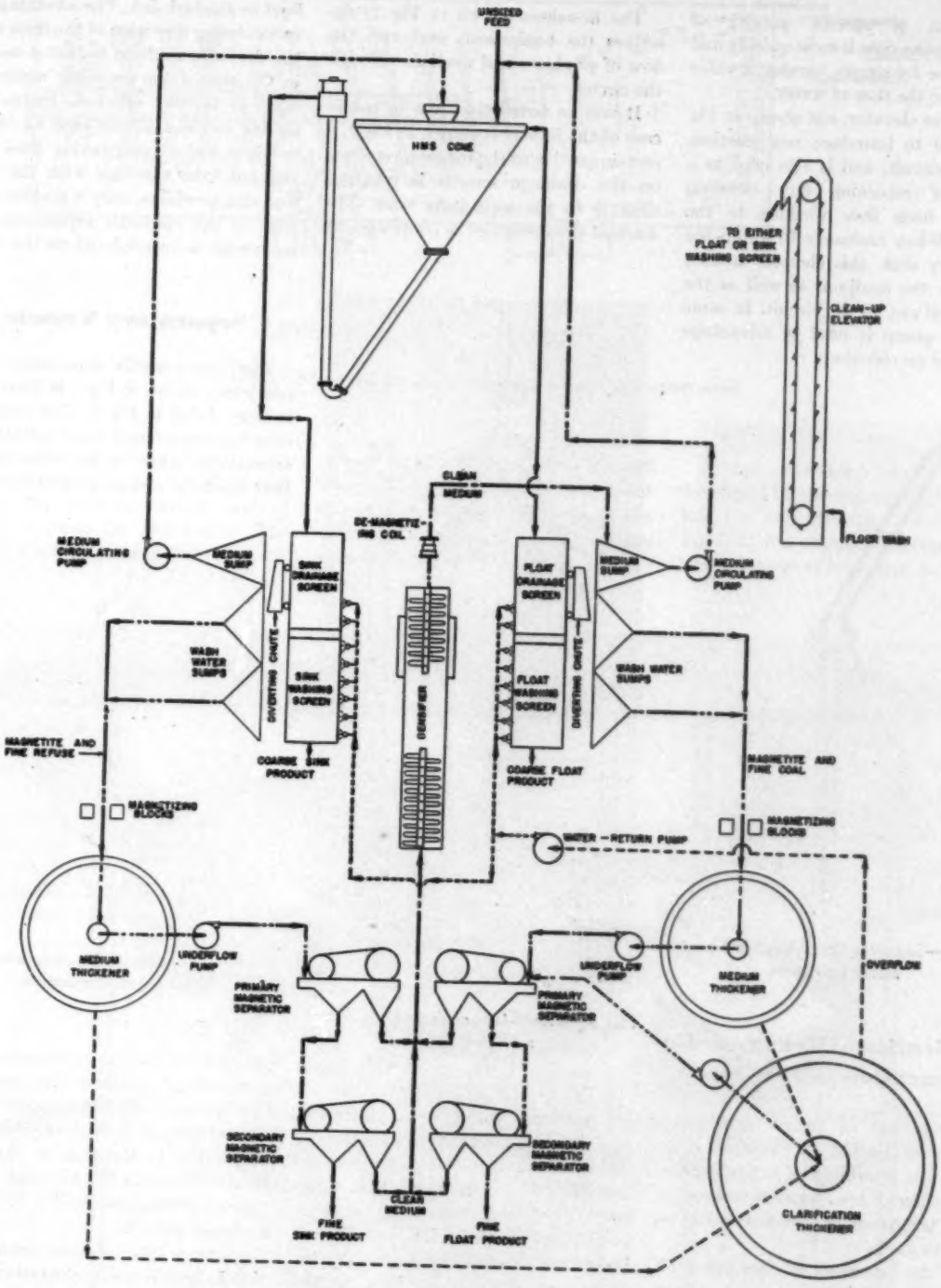

FIG 2—Flowsheet of treatment commonly used for sizes below 10 mesh.

adjustment of specific gravity of medium in the cone is most quickly and easily done by simply turning a valve to regulate the flow of water.

A bucket elevator, not shown in Fig 1, is used to introduce new medium into the circuit, and is also used as a means of returning any clean-up material from floor washing to the system. When necessary to dump the separatory unit, this elevator is used to return the medium, as well as the intermixed ore, to the circuit. In some plants a pump is used to advantage instead of an elevator.

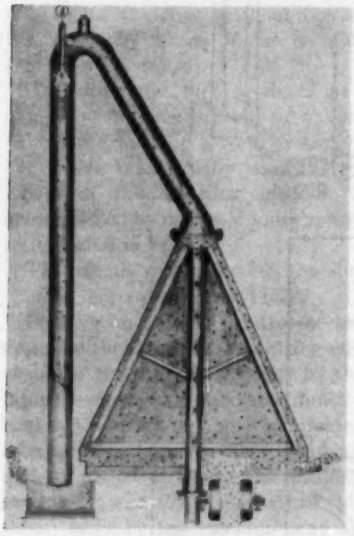

FIG 3—Separatory cone used in heavy-media separation.

Application of Heavy-media Separation to Fine Sizes

The results of recent continuous pilot plant testing at Stamford have shown the possibility of extending the application of heavy-media separation to the treatment of material as fine as 28 to 48 mesh.

For the treatment of sizes below 10 mesh, a modified flow scheme has been developed. Essentially, this involves the use of dual magnetic cleaning circuits wherein the undersize float and the undersize sink products from the screens are separately subjected to magnetic separation. The magnetic separators recover the medium for re-use and the tailings from these separations are either a finished float or a finished sink product, as the case may be.

The flowsheet shown in Fig 2, describes the equipment used and the flow of products and medium through the circuit.

It will be noted that just as in the case of the flowsheet shown in Fig 1, a certain portion of the medium removed on the drainage screens is returned directly to the separatory cone. The amount thus returned is controlled by the position of the diverting chute and is dependent upon the quantity of undersize float and sink in the original feed. It will be apparent that when treating a feed containing a large proportion of undersize material, it becomes necessary to divert a greater amount of drainage medium to the cleaning circuit than would be the case when the cone feed contains a smaller proportion of fines. In other words, the amount of fine material that can be recirculated to the cone with the medium depends on just how much can be tolerated in the cone without interfering with the separating efficiency of the medium. Eventually, of course, all of the fine material in the separatory cone circuit reports as finished float or finished sink. The advantage of recirculating a portion of the fines with the drainage medium is that a saving in the size of the magnetic separator units is thereby effected. Instead of having to clean at one time all of the medium and accompanying fines discharged from the cone with the float and sink products, only a portion of it goes to the magnetic separators; the remainder is recirculated to the cone.

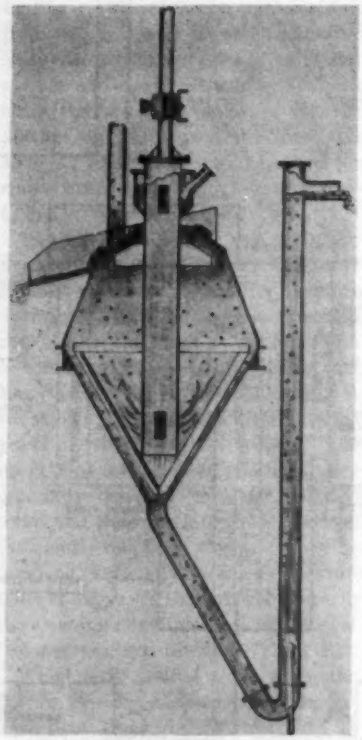

FIG 4—Closed-top cone used in heavy-media separation.

Separatory Vessels

The heavy-media separatory cone previously shown in Fig 1 is illustrated in more detail in Fig 3. This open top cone has been found most suitable for separations where a large amount of float has to be removed. In other cases, particularly for the treatment of iron ores where a finished sink product is required and where the amount of float to be removed is relatively smaller in proportion to the sink, a closed top cone as shown in Fig 4 is used. A third type of cone, shown in Fig 5, employs an inside air lift.

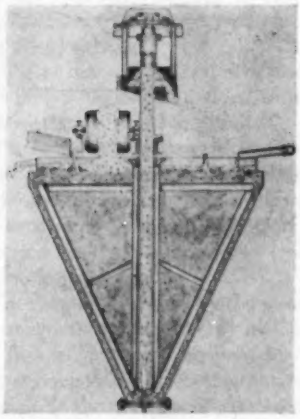

FIG 5—Inside air lift cone used in heavy-media separation.

All three types of cones are in operation in heavy-media separation plants.

The cone separator fitted with an inside or an outside air lift is an efficient, flexible, and economical vessel.

The scope of the heavy-media separation processes is not limited to the use of cone-shaped separators, however. Other shapes have been developed and used for ores presenting special problems of treatment.

The Colorado Iron Works have adapted the Akins classifier for use as a

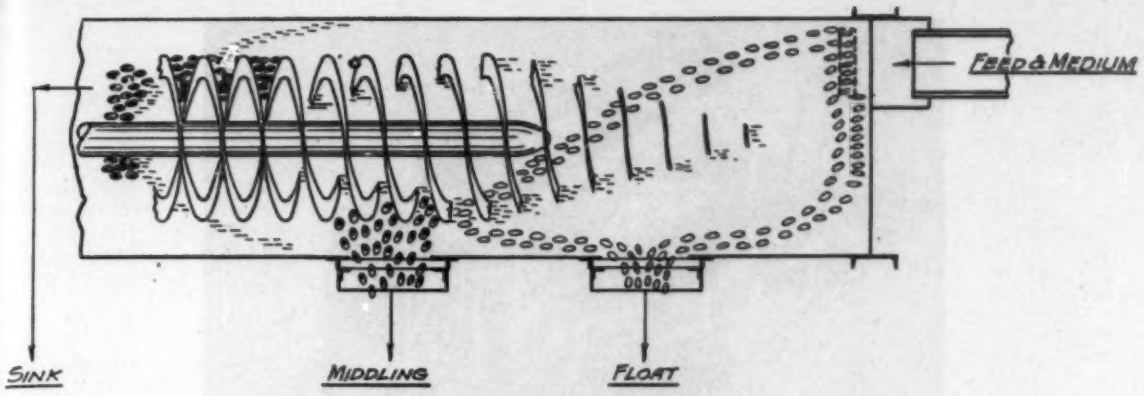

FIG 6—Akins classifier adapted for heavy-media separatory vessel.

heavy-media separatory vessel. This unit is illustrated in Fig 6 and has had outstanding success treating ores of the iron range in Minnesota. The principal advantages of the vessel are reduced head room and elimination of the air lift for sink removal. The plant can be shut down at the end of the shift, or in event of power failure, without draining the vessel.

A new separatory vessel has been develõped by the engineers of the Link-Belt Co. This machine is illustrated in Fig 7. It was designed particularly for the treatment of large size coal. A unit

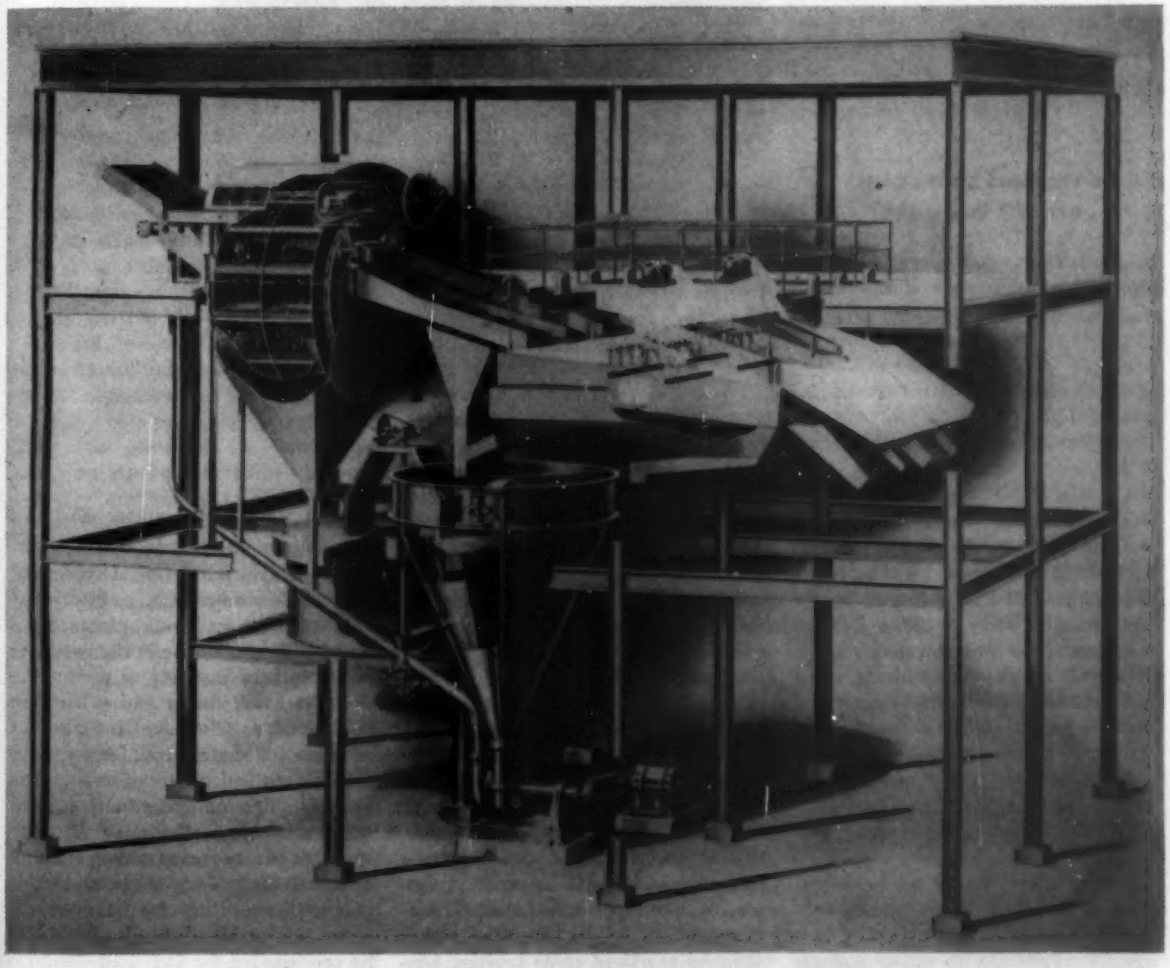

FIG 7—Link-Belt float-sink concentrator showing separatory vessel in upper left.

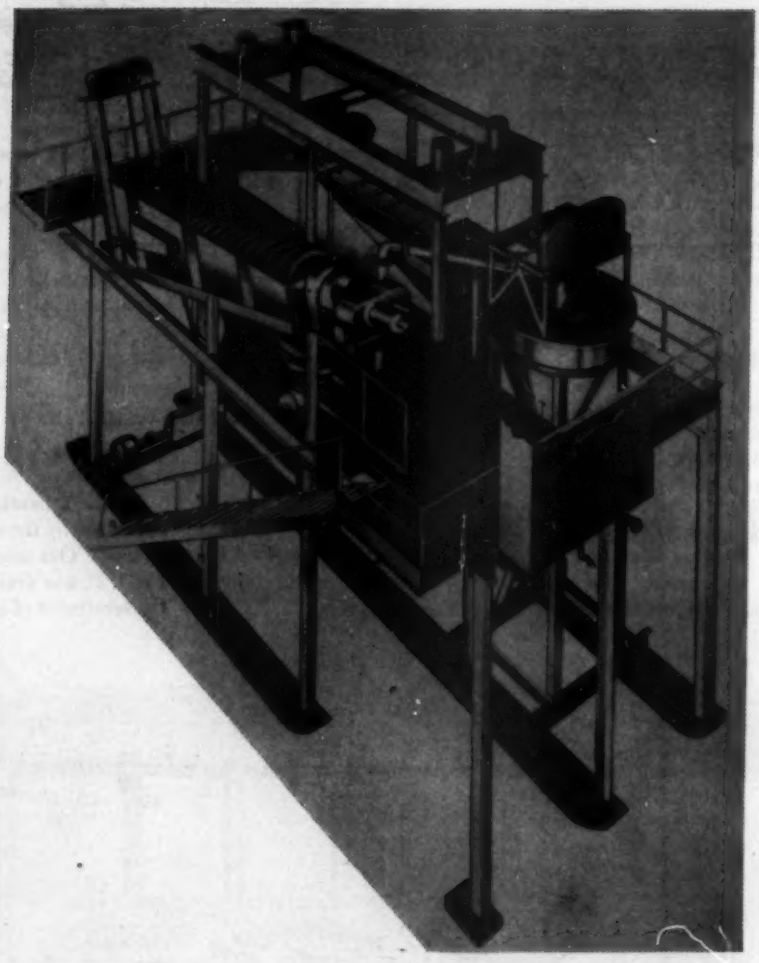

FIG 8a—Typical portable heavy-media separation unit.

was installed in an operating coal cleaning plant in the Pittsburgh district about two years ago. The vessel has demonstrated its ability to handle mechanically large coal and large tonnages. Plans are now being made to install Link-Belt vessels in what will be one of this country's largest coal cleaning plants. Several smaller installations also are contracted for.

Small Tonnage Unit

Although heavy-media separation processes have found their widest application in operations treating substantial daily tonnages, they are equally applicable to small tonnage operations.

For concentrating ores from deposits with limited reserves, mine dumps, and retreatment of coarse gravity tailings piles, or to serve as a pilot plant for demonstrating the efficiency of heavy-media separation on current production or during development of new properties, a semiportable heavy-media separation unit has been developed. In this unit the essential pieces of equipment have been reduced to meet minimum requirements consistent with high separating efficiency in order that capital costs may be reduced to a minimum. As might be expected, operating costs per ton for the semiportable unit will be somewhat higher than for standard units treating tonnages at a higher rate. A typical unit of this type is the Mobil-Mill offered on a rental or sale basis by Western-Knapp Engineering Co., Division of Western Machinery Co., as illustrated in Fig 8. These small plants have found wide application in the industry. Six have been installed as production units at small mines and others are being used as pilot plant installations at producing shafts. Rock from various sections of the deposit can be tested as well as mine output resulting from various mining methods. In this way the most advantageous mining method, economic limit of ore grade, and value of preconcentration by heavy-media separation can be determined and can be coordinated for the most desirable overall operation.

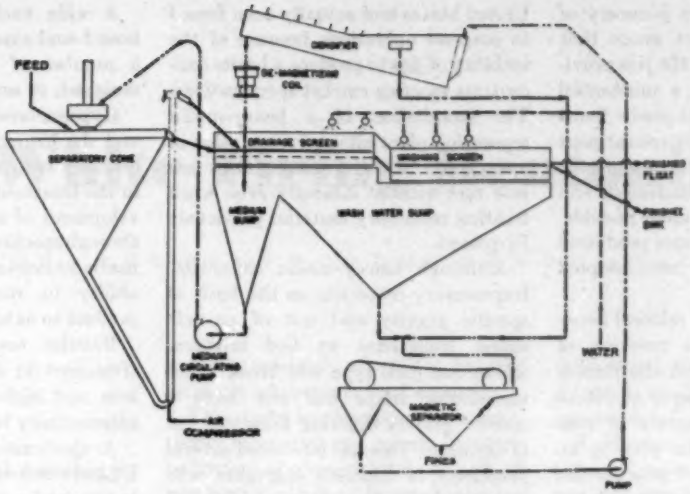

FIG 8b—Diagram of portable heavy-media separation unit.

Separatory Medium

The ideal separating medium obviously would be one having the low viscosity and high stability (uniform gravity from top to bottom) of heavy liquids. When dealing with a suspension of a solid in water both these ideals cannot be attained. Reduction of the particle size of the suspended solid will decrease the settling rate of the solid and thus increase the stability of the suspension but will increase the viscosity because of the increased surface area generated. A compromise must be reached, therefore, between stability and viscosity. The open-top cone shaped separator permits sacrifice of stability so as to maintain the low viscosity essential for maximum settling rate of fine heavy ore particles and hence high tonnage and accurate separation. The unstable suspension results in a differential density; the specific gravity at the bottom of the bath will be higher than at the top. The differential between top and bottom gravities will normally be in the neighborhood of 0.10 to 0.25 in the case of a 20 ft diam cone, which with 60° sides would be over a vertical distance of 17 ft. Obviously the differential existing in top 6 or 8 in. of the bath where the actual separation takes place will be exceedingly small and cannot conceivably influence the separation. In any vessel other than a cone, such a differential density could not be tolerated because any ore would contain some particles having a specific gravity between the top and bottom gravities in the cone, and such pieces would come to rest or teeter when they reached a zone having a specific gravity equal to their own. An accumulation of such material would ultimately plug the cone if it were not for the differential downdraft created by the operation of the air lift. Air lifts normally are designed to have a pipe velocity of about 6 ft per second. This velocity exists at the intake opening of the air lift. At various horizons above the air lift intake, the downdraft diminishes in proportion to the diameter of the cone at such horizons. The medium circulated by the air lift is returned to the cone at any desired level or levels. In this way the downdraft of the air lift can be satisfied before its influence is felt in the top 6 or 8 in. of the bath which is the separating zone.

From the foregoing, it will be seen that the combination of ferrous media, magnetic cleaning and control, and the cone with air lift combination has eliminated the difficulties with which the various sink-float methods have been confronted.

Magnetic cleaning permits the use of the size and type of medium best suited for any operating gravity between 1.25 and 3.40 so as to develop a reasonably stable medium.

Operating Industrial Mineral Plants

Many successful applications of heavy-media separation to industrial mineral beneficiation problems have already been established.

At Chewelah, Wash., the Northwest Magnesite Co. is beneficiating approximately 150 tons per hour of magnesite mixed with dolomite, shale, and quartz. The quarry product is crushed to minus 1½ in. and the minus $\frac{3}{16}$-in. portion is removed. The minus 1½ in. plus $\frac{3}{16}$ in. rock is fed to a 20 ft diam outside air lift cone. The specific gravity of the separation medium is varied between 2.80 and 3.00 depending on the grade of magnesite desired.

At this operation heavy-media has replaced a large group of hand pickers who formerly picked magnesite from broken rock at the quarry face. The economy of operation and the efficiency of separation obtained by heavy-media has made it possible to retreat profitably the rejects from the hand picking operation.

At Rosiclare, Ill., the Rosiclare Lead and Fluorspar Mining Co. is treating in the neighborhood of 40 tons per hour of fluorspar ore. The flexibility of

heavy-media provides an accuracy of control over the product grade that was never obtained with the jigs previously used. In addition, a substantial tonnage of metallurgical-grade fluorspar has been recovered by retreatment of old jig tailings. Operating costs have been reduced, recovery increased, and accurate product control made possible.

Most of the other fluorspar producers in the Rosiclare district have adopted heavy-media.

An unusual industrial mineral beneficiation problem is the recovery of garnet from hornblende at the Barton Mines Corporation property at North Creek, N. Y. Approximately 40 tons per hour of minus 1¼ in. plus ⅛ in. quarry product is treated at a specific gravity of 3.17. Heavy-media replaced jigs at this operation. Costs have been reduced and recovery improved.

The application of heavy-media separation to coal cleaning problems is now being studied. A pilot plant with a capacity of 250 tons per hour has been in operation in one of the Pittsburgh Coal Company's plants for over two years. The feed to heavy-media is 4 by ⅜ in. secondary middling from an older coal cleaning process. The ability of heavy-media to recover clean coal from such a product has demonstrated the efficiency of the process. Several large tonnage heavy-media plants are now under construction or are being designed for coal treatment, both bituminous and anthracite.

Laboratory tests followed by a year's operation of a 100 ton per hour pilot plant have demonstrated the superiority of heavy-media over older methods for the recovery of diamonds in Africa. A 12,000 ton plant has been designed and is now under construction.

A barite producer in Southeastern United States had actually been forced to suspend operations because of the inability of jigs to produce a barite concentrate meeting market specifications. The installation of a heavy-media separation plant allowed resumption of operations. Market specifications are now met without difficulty even when treating refractory material previously by-passed.

Although heavy-media separates fragmentary materials on the basis of specific gravity and not of particle shape, sometimes we find mixtures where one rock type will break to an undesirable shape and also have a specific gravity differing from the rest of the mass. This has interested several producers of concrete aggregate who are troubled by excessive "flats." Laboratory tests have demonstrated the ability of heavy-media to eliminate "flats" from aggregate because in most cases a substantial difference in specific gravity exists.

A heavy-media separation plant is now in satisfactory operation at the site of a large concrete project. Local gravel is being cleaned of undesirable rock types, and concrete made with this aggregate has been pronounced excellent after government laboratory tests. The elimination of an expensive freight haul has made this a most profitable operation.

Laboratory Testing

At the Research Laboratories of the American Cyanamid Co., at Stamford, Conn., the Mineral Dressing Division maintains equipment capable of treating from 200 lb to as high as 5 tons per hour by heavy-media to determine the amenability of any type of material to beneficiation.

A wide variety of materials have been found amenable to treatment and a number of new plants are being designed, or are under construction.

Gypsum ores from England, Canada, and the United States have been successfully treated. Of particular promise in the treatment of gypsum was the development of accurate product control through specific gravity control. Heavy-media promises a gypsum producer the ability to vary the quality of his product so as to meet market demands.

Bauxite ores have responded to treatment in some cases. Both high-iron and high-silica types have been substantially beneficiated.

A spodumene producer in Western United States has had small scale heavy-media tests conducted on his ores. The results obtained have been so satisfactory that a plant is now being installed and will be in operation in the near future.

Tests on a Canadian corundum ore have shown the ability of heavy-media to produce a satisfactory product from low-grade rock.

Potash ores have been treated by heavy-media using a suspension of magnetite in saturated brine and three product separations have been made in several cases—a coarse finished product, a coarse reject, and a middling product requiring fine grinding prior to froth flotation or leaching.

One producer of railroad ballast has shown considerable interest in heavy-media separation because laboratory tests have demonstrated the ability of the process to eliminate a low specific gravity rock from his quarry output. The use of full face mining followed by heavy-media offers cost reduction, accurate product control, and greatly extended quarry life to this producer.

Texas White Firing Bentonite

BY FORREST K. PENCE

Location, General Geology, and Development

BENTONITE deposits are known to occur in Texas within the Jackson group of formations. This group represents the uppermost Eocene age sediments found in the coastal plain area of Texas. It outcrops across this area of the state in a narrow band of some 4 to 20 miles width. The outcrop pattern roughly parallels the present Gulf of Mexico shore line and is some 100 miles inland from the Texas shore, Fig 1.

The principal bentonite deposits are found in the areas where this outcrop pattern cuts across the south-central Texas counties of Karnes, Gonzales, and Fayette. In these deposits, the better quality bentonite is found in the lower or bottom layers of the volcanic ash deposits in which they occur.

Some of these better quality bentonites develop very light colors upon firing and therefore justify their being classified as "white firing." The deposits in Karnes and Gonzales Counties apparently occur in commercial quantity, whereas the white firing strata so far uncovered in Fayette County have been too thin to be classified as yet as "commercial." A study of the ceramic properties of the weathered ash in Gonzales and Karnes Counties was reported in 1941.[1]

Commercial development of the deposit in Gonzales County, 7 miles east of Gonzales, Texas, was started earlier by the Max B. Miller Co. for the purpose of marketing the material as a bleaching clay, and this operation has developed to very sizable proportions. In recent years, this company has offered a specially selected grade of the Gonzales material as a suspending agent in glaze slips. The white firing property especially adapts the material to use in white cover coat enamels.

The strata in the deposit are practically horizontal and consist from top to bottom of approximately 2 ft of soil overburden, 10 ft of brown bentonite, 2 ft of coarse white bentonite, and 4 ft of waxy white bentonite overlying a fine grained sandstone. The cut being made in the quarry is approximately one-half mile in length. Only the bottom 4 ft of waxy bentonite is being recovered, the upper layers being stripped and wasted, Fig 2. It may appear somewhat surprising that the very bottom strata appears to have been the one most completely altered.

To confirm this, samples from top to bottom of the various strata were studied microscopically by R. F. Shurtz, Professor of Ceramic Engineering, University of Texas. His interpretation is to the effect that the lower part of the seam was deposited at a much earlier date than the top, and that the lower part was chemically altered to a considerable extent before the upper part of the seam was laid down. The conclusion to be derived from these examinations may be stated briefly to be that the alteration in these strata or parts of strata has proceeded independently of the alteration in other parts of the strata during a considerable geological period. The presence of gypsum and iron stain throughout all of the strata indicates that alteration is now proceeding more or less uniformly throughout. It is contended that the alteration of the original ash to montmorillonite is not a result of the presently operating processes.

A deposit which occurs approximately 7 miles southeast of Falls City and just south of the village of Castahowa, has been explored and leased by J. R. Martin, of San Antonio. Mr. Martin has conducted mining and marketing operations in bentonite for a period of many years and asserts that the white firing strata found in this deposit occurs in commercial quantities. His pit, which is shown in Fig 3, exposes 2 ft of soil overburden, approximately 5 ft of white bentonite having coarse texture, and approximately 5 ft of waxy white bentonite which in turn overlies a brown sandy clay. Here, as in the Gonzales deposit, the most completely altered portion is found at the bottom of the seam, as per following report of microscopic examination by Mr. Shurtz.

Sample No. 1: This sample was taken from the top stratum which is one foot thick. It is grayish in color and it contains visible fossilized plants. The color is probably the result of fine carbonaceous material in the rock. Under the microscope the sample is seen to consist of glass and feldspar; the amount of glass predominating. Both these substances are slightly altered. No montmorillonite or other clay mineral can be identified definitely; however, the products of the slight alteration mentioned are probably montmorillonite or mineral gel.

Sample No. 2: This sample was taken from the stratum second from the top. This stratum is fourteen inches thick. The sample is light gray. It shows numerous veinlets of greenish translucent material ranging from one-eighth inches wide down to the limit of visibility with the unaided eye. It has the smooth, sub-conchoidal fracture characteristic of some bentonites.

Microscopically the sample consists mainly of aggregates of clay minerals. The birefringence of the aggregates is lower than would be expected if the

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TP 2504 H. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before March 30, 1949. Manuscript received Nov. 4, 1946; revision received Aug. 24, 1948.

* Department of Ceramic Engineering, University of Texas, Austin, Texas.

[1] Forrest K. Pence: White Firing Texas Volcanic Ash as a Body Ingredient. Amer. Ceramic Soc. *Bull.* (1941) **20** (10) 327.

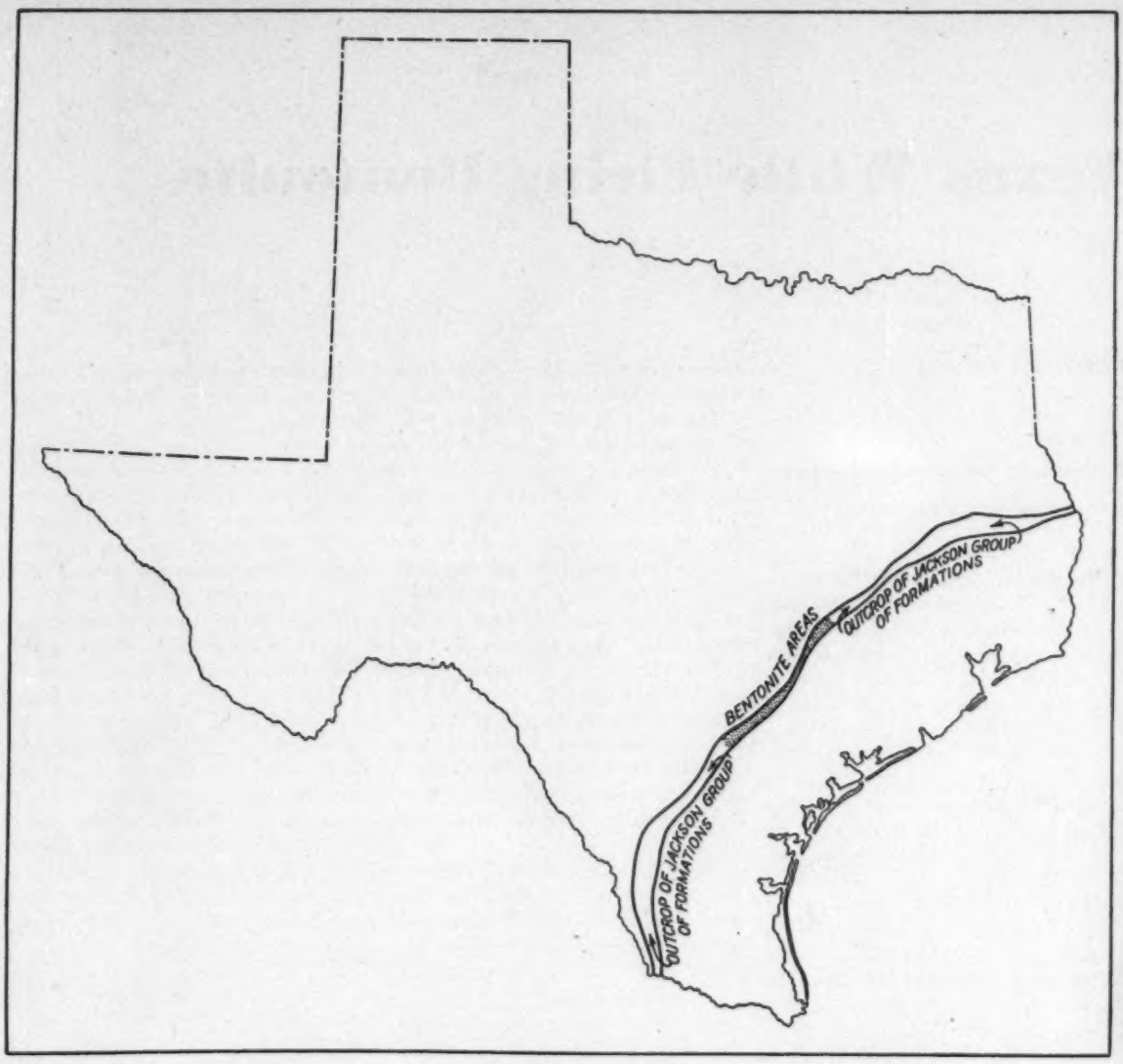

FIG 1—Map of Texas showing outcrop of Jackson group of formations and bentonite areas.

aggregates were pure montmorillonite; on the other hand, the birefringence is higher than expected if the aggregates were pure minerals of the kaolin family. The veinlets mentioned above furnish a clue for the explanation of the anomalous birefringence. Powder taken from the veinlets is isotropic, or nearly so, and the index of refraction is 1.48. These optical properties and the occurrence identify the material in the veinlets as a mineral gel similar to allophane. Inasmuch as the aggregates are not optically homogeneous, they are assumed to be intergrowths of montmorillonite and mineral gel.

Residual glass and feldspar are present in this sample in small amount.

Sample No. 3: This sample was taken from the stratum third from the top. This stratum is one foot thick.

The microscope shows some aggregates of clay minerals that are not noticeably different from those aggregates observed in Sample No. 2. However, there is much slightly altered glass and feldspar in this sample and the aggregates are in lesser amount than the glass and feldspar.

Sample No. 4: This sample was taken from the stratum fourth from the top of the deposit. This stratum is eighteen inches thick.

The microscope shows aggregates of clay minerals; but these aggregates have higher birefringence than those in Samples No. 2 and No. 3. For this reason the amount of montmorillonite is thought to be much greater than the amount of mineral gel. There are traces of glass and feldspar in the sample.

Sample No. 5: This sample was taken from the stratum fifth from the top of the deposit. The stratum is eighteen inches thick and is lowermost in the deposit.

The microscope shows this sample to be similar to Sample No. 4 in all respects except that the amount of glass and feldspar appears to be still less than the amount in Sample No. 4.

Summary: On the assumption that the volcanic ash in each of these five strata was originally more or less the same, the existing differences among the strata can be explained only by differences in the amounts and kinds of alteration to which the strata have been exposed. The three lower strata show alteration paralleling the order of deposition; that is, the lowest and oldest stratum is most altered whereas the uppermost and youngest of the three is least altered. This is quite understandable because, if alteration began immediately after deposition, the oldest stratum would be most altered. However, the second stratum from the top, younger than any of the lower three, shows alteration advanced much beyond that of the stratum below it. This fact cannot be explained by age alone and appeal must be made either to a change in the character of the ash or to a change in the altering environment or to both possibilities. The examination made and reported here was not sufficiently detailed to discriminate between these possibilities.

Physical and Chemical Properties

All laboratory determinations reported in this paper were made on the lowermost strata consisting of waxy white bentonite. These strata also developed the whitest color in the firing tests. In the course of the investigation of the material in the ceramic laboratory, absorptions and shrinkages were determined over a range of temperature between Cone 07 and Cone 13. This study disclosed the fact that the bentonite at Gonzales is much more refractory than that at Falls City, as is shown in Table 1.

Table 1 . . . Fired Properties of the Raw Bentonites

Cone	Gonzales		Falls City	
	Fired Shrinkage, Per Cent	Absorption, Per Cent	Fired Shrinkage, Per Cent	Absorption, Per Cent
07	7.00	20.48	14.57	5.20
06	7.17	15.61	14.97	2.69
03	7.51	17.93	18.11	0.60
01	8.19	16.17	15.36	0.17
1	7.51	17.07	14.97	0.35
3	7.51	17.96	14.97	0.23
4	7.51	18.63	14.57	0.38
5	8.19	16.42	12.20	0.00
8	9.22	13.88		
9	9.39	13.64		
11	9.39	15.14		
13	11.43	10.02		

The study of the bentonites from the two quarries brought out in addition physical properties shown in Table 2.

Chemical analyses were then made with the results given in Table 3.

Examination of chemical analyses does not reveal sufficient differences in composition to explain the differences of the physical properties of the two bentonites.

Materials were then examined by thermal analysis, Fig 4. That from Falls City shows a large endothermic reaction at 1500°C and a small endothermic reaction at 700°C, which are characteristic features of the mont-

FIG 2—Exposure of Gonzales bentonite strata.

FIG 3—Exposure of Falls City strata.

Table 2 . . . Physical Properties of Bentonite from Gonzales and Falls City Quarries

Pyrometric Cone Equivalent (PCE): The method of testing followed the procedure specified by the A.S.T.M. designation: C 24–46. The PCE determination is made, therefore, by comparison of temperature of deformation of test cones made of the bentonites with corresponding deformation of standard pyrometric cones.

PCE

Gonzales bentonite	Cone 15
Falls City bentonite	Cone 9

Volume Changes in Swelling Tests: Comparisons were made of the swelling properties of the bentonites in question along with standard Black Hills bentonite and a typical domestic kaolin.

Material	Volume Increase, Per Cent	Volume Decrease, Per Cent
Black Hills bentonite	700	
Gonzales bentonite	100	
Falls City bentonite	40	
North Carolina kaolin		30

The volume increase for the Gonzales bentonite is typical of those Texas bentonites which possess the swelling property. The Falls City would be classified as practically non-swelling.

Determination of Drying Shrinkage. Bars made up in the plastic form, determination made in the usual manner.

Material	Drying Shrinkage, Per Cent
Gonzales bentonite	5.9
Falls City bentonite	12.1

Table 3 . . . Chemical Analysis of White Firing Bentonites

Component	Gonzales, Per Cent	Falls City, Per Cent
Ignition loss	9.16	12.70
Silica	71.00	66.64
Alumina	13.00	14.05
Ferric oxide	0.85	1.19
Calcium oxide	1.20	0.46
Magnesium oxide	2.04	2.26
Sodium oxide	2.30	2.56
Potassium oxide	0.60	0.60
	100.14	100.46

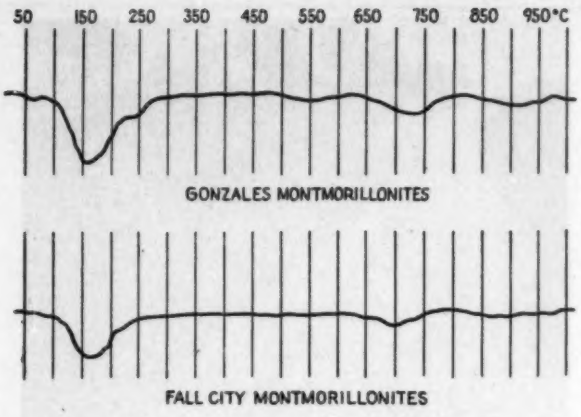

FIG 4—Thermal analysis curves of white firing montmorillonites (Texas).

morillonite series of minerals. That from Gonzales shows in addition to the two endothermic reactions (at 1500°C and 700°C) an endothermic reaction at 600°C and an exothermic reaction at 950°C, characteristic of a kaolin mineral.

Mineralogical Identification

A study of the two bentonites under the electron microscope indicates that the Falls City material consists of practically pure montmorillonite, whereas the Gonzales carries with the montmorillonite, halloysite as an accessory mineral. The oblong-like crystals, (Fig 6 and 7) identify the accessory mineral as halloysite. The nebulous particles seen in the micrographs are characteristic of montmorillonite.

As a final determination of the mineral composition, X ray diffraction patterns were made using the Norelco Geiger X Ray Spectrometer (Fig 5). The pattern for the Gonzales sample shows montmorillonite, halloysite and possibly crystobalite, as indicated by several lines that could be attributed to that mineral. The presence of crystobalite tends to be confirmed also by the high silica content (Table 3).

The pattern for the sample from Falls City checks closely with montmorillonite from Arizona which is an approximate standard of purity. There are a few lines in this pattern also that check with the data for crystobalite. The Falls City bentonite is, therefore, thought to be a montmorillonite with a moderate quantity of crystobalite.

Industrial Uses, Present and Potential, as Shown by Laboratory Tests

The Gonzales bentonite is being mined extensively and processed for use as a bleaching clay. It is thought that the Falls City material can be similarly utilized although the occurrence of Falls City is probably not as extensive as the one at Gonzales. Especially selected material from the Falls City deposit could also be used as a suspending agent in enamel slips, as is already being done with the Gonzales material as previously pointed out.

The white firing quality of the bentonites made them the object of special interest as ingredients in porcelain and semiporcelain compositions. In this investigation standard porcelain body compositions were made in which substantial quantities of the Gonzales bentonite and the Falls City bentonite were incorporated, with the result that it was shown that these materials gave a longer plasticity range and greatly increased drying strength and improvement in glaze fit. The body made with Gonzales bentonite has a high degree of whiteness, whereas, that using bentonite from Falls City tends to approach the ivory shade. Because of the strength and dense burning quality of the bentonite from Falls City, however, it could be used judiciously to replace ball clay and feldspar where a maximum degree of whiteness is not required.

These bentonites possess another quality which has yet to be overcome. They tend to give a sticky type of plasticity rather than the smooth, oily feel of normal ball clay. Further, in casting process the slip made of the powdered material and water tends to form gels that slow down the casting properties and cause sticking to the mold. This property of a slip is desig-

Table 4 . . . Body Compositions

	Test Number		
	EB-8	EB-9	EB-10
Troup ball clay*	25	25	25
Raw Gonzales bentonite	15	8	8
Davis Mountain kaolin	45 raw	52 raw	52 heated to 350°
Falls City bentonite (calculated at cone 06)	15	15	15
Dolomite	4	4	4
Determined data			
Total shrinkage	20.0	20.0	14.5
Absorption	6.5	4.6	4.8

* From Troup.

Table 5 . . . Body Compositions

	Test Numbers			
	EB-16	EB-17	EB-20	EB-21
Troup ball clay	25	25	25	25
Gonzales bentonite (raw)				5
Falls City (calulated at cone 016)	20	20	20	20
Teague kaolin* (raw)	51	35		
Davis Mountain kaolin (350°C)			35	35
Dolomite	4	4	4	4
Flint		20	20	15

* Obtained near Teague, Freestone County.

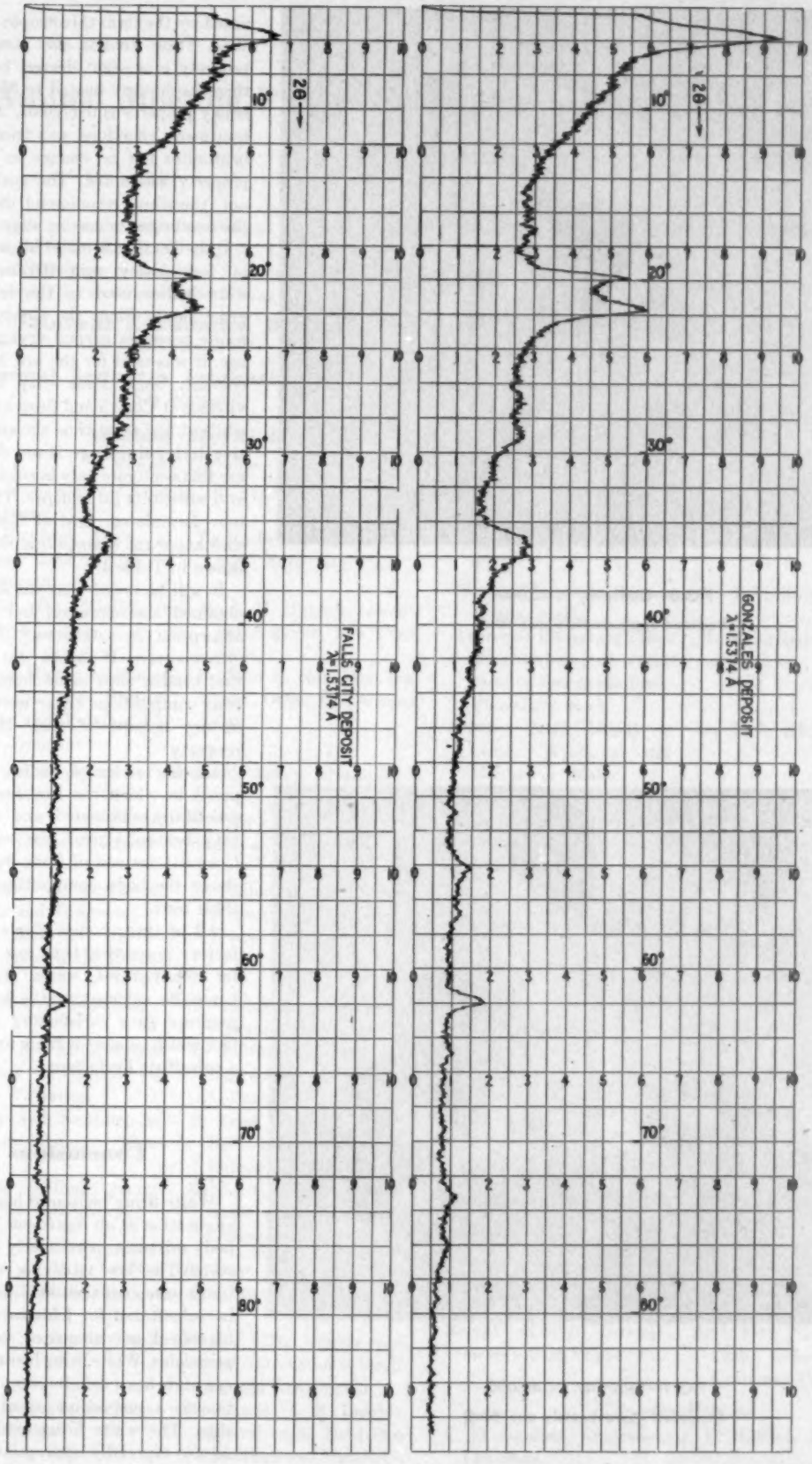

FIG 5—X ray diffraction patterns. Upper half, Gonzales; lower half, Falls City.

FIG 6—Gonzales. × 40,000.
(Reduced approximately one third)

FIG 7—Falls City. × 40,000.
(Reduced approximately one third)

nated by the term thixotropic. Certain West Texas kaolins also possess this property in a slight degree, but when these kaolins are heated to 350°C this sticky property is overcome. A similar treatment, therefore, was tried on the bentonites but no change in physical property was noted. The author cannot, therefore, recommend the use of the bentonites in casting slips.

Only Texas raw materials were used in formulating semivitreous dinner ware bodies used in the laboratory experiments. Since the Gonzales bentonite possesses normal drying shrinkage, it was used for the raw bentonite content. Since Falls City bentonite vitrifies at Cone 5 and fuses at Cone 9, while at the same time showing excessive drying shrinkage, it was decided to use this bentonite only in calcined form as a substitute for feldspar. The bodies were formulated, fired at Cone 8, and shrinkages and absorptions obtained as shown in Table 4.

It will be noted that the shrinkages obtained are excessive, but that the absorption is satisfactory for semivitreous ware. It should also be noted that casting slips made from the raw body compositions above were unsatisfactory because of their thixotropic property.

Another series of bodies was prepared in which the raw bentonite is practically eliminated and the Falls City bentonite used was calcined at Cone 016 instead of Cone 06. Table 5 shows the body compositions used in these tests.

All of these bodies displayed satisfactory properties, both raw and fired, for semivitreous wares. Falls City bentonite calcined at the lower temperature gave satisfactory results, a fact which renders it more available as a substitute for feldspar.

Conclusions

White firing bentonite has a limited application as an ingredient in ceramic body mixtures, particularly in the raw state. The low vitrifying white bentonite when calcined at Cone 016, can be substituted for feldspar as a body ingredient in vitreous or semivitreous porcelains. White firing bentonite in the raw state has a definite ceramic application as a suspending agent in enamel slips. The white firing quality makes its use especially appropriate in white firing enamels.

Annual Meeting Papers Scheduled by the Mining Branch, By Sessions

For preview and chart of sessions of the entire Annual Meeting AIME, San Francisco, Feb. 13-17, see page 14, of the All-Institute section (Sec. 2), this issue. The technical papers by sessions for the Mining Branch follow:

Mineral Economics Division

See Section 2

Mineral Industry Education Division

See Section 2

Mining Methods

Monday Afternoon

C. M. Romanowitz, Chairman; K. Fritz Eilers, Associate Chairman.

One Hundred Years of Placer Gold Mining in California.	By Herbert A. Sawin, sales mgr., Yuba Mfg. Co.
Alluvial Tin Mining in Malaya.	By A. D. Hughes, consulting engineer, San Francisco.
Opencut Mining in Minnesota in the Postwar Years and Possible Future Trends.	By John H. Hearding, gen. supt., Oliver Iron Mining Co.

Color motion pictures of the South Agnew stripping operation.

Tuesday Morning

Guy N. Bjorge, Chairman; Lynn Hersey, Associate Chairman.

The Use of Percussion Drills and Tungsten Carbide Bits for Drilling Blastholes at the Holden Mine.	By Elton A. Youngberg, mining engineer, Howe Sound Co.
Diamond Drill Sampling.	By Josiah Royce, geologist, Pickands, Mather and Co.
Hazard and Enhancement Factors as Related to Mine Valuation.	By J. Murray Riddell, mining engineer, Michigan College of Min. & Tech.
Drilling and Sampling of Unconsolidatory Materials.	By Leon W. Dupuy, chief, Rolla mining div., U. S. Bureau of Mines.
Diamond Drilling Quartz-feldspar Intergrowths.	By Lee C. Armstrong, asst. chief geologist, E. J. Longyear Co.

Tuesday Afternoon

Henry C. Carlisle, Chairman; E. R. Borcherdt, Associate Chairman.

Sublevel Stoping in Small Mines.	By J. J. Lillie, mining engineer, International Smelting and Refining Co.
A New Incline in the Metaline District.	By Charles A. R. Lambly, general supt., Pend Oreille Mines and Metals Co.
Operations at the San Xavier Mine of Eagle-Picher Mining and Smelting Company.	By G. W. Irvin, mining engineer, Eagle-Picher Mining and Smelting Co.
Attracting Men to the Mining Industry.	By J. K. Richardson, manager, Utah Mining Association.

Wednesday Morning

Symposium on Phosphate Mining
(Joint session with Industrial Minerals Division)

E. M. Norris, Chairman.

Foreword.	By E. M. Norris.
Geological Studies of the Western Phosphate Field.	By V. E. McKelvey.
Mining Phosphate Rock at Conda, Idaho.	By T. C. Russell.
Anaconda Phosphate Plant, Beneficiation and Treatment of Low-grade Idaho Phosphate Rock.	By R. J. Caro.
Surface Strip Mining at Leefe, Wyoming and Montpelier, Idaho.	By D. L. King.
Mining Operations at Garrison and Avon, Mont.	By Robert J. Armstrong and J. J. McKay.
Surface Mining Operations Near Fort Hall, Idaho.	By Heath B. Fowler.

Wednesday Noon

Luncheon Meeting. F. A. Wardlaw, Jr., Committee Chairman, presiding.

Motion pictures of old Cornish pumps in England.

Wednesday Afternoon

L. A. Walker, Chairman; Carroll Weed, Associate Chairman.

Safe Practices in Block-cave Mining.	By R. H. Wightman, mine supt., Riverside Cement Co.
Caving Operation, Asbestos, Quebec, Canada.	By Gerald Sherman, Basin Montana Tunnel Co.
Summary of Block-caving Operations.	By R. W. Thomas, general manager, Nevada Consolidated Copper Co.
Factors Governing Mechanization.	By C. Kremer Bain, asst. to general mgr., St. Joseph Lead Co.
Recent Mining Developments—Utah Copper Pit.	By L. Fern Pett, asst. supt., Utah Copper division, Kennecott Copper Corp.

Thursday Morning

E. D. Gardner, Chairman; J. B. Haffner, Associate Chairman.

Mechanical Equipment at the Bureau of Mines Oil-shale Experimental Mine.	By E. D. Gardner and Emery Sipprelle, Bureau of Mines.
Stresses Around Mine Openings.	By Lewis A. Panek, Columbia University.
Dump Leaching at Chino.	By A. F. Morris, asst. mine supt., Chino Consolidated Copper Co.
History of Pumping at Chief Consolidated Mine at Eureka, Utah.	By J. G. Hall, general supt., Chief Consolidated Mining Co.

Health and Safety in Mines

Monday Morning

Advances in Measurement and Control of Mine Dusts.	By W. C Williamson and J. L. Shugert, Anaconda Copper Mining Co.
What's New in Mining Safety?	By J. J. Forbes, chief, Health and Safety Div., and S. H. Ash, chief, Safety Branch, U. S. Bureau of Mines.
Safety in Mining at the Andes Copper Mining Co.	By Charles M. Brinckerhoff, gen'l mgr., Andes Copper Mining Co.
Practices in Health and Safety in Pioche.	By S. S. Arentz, general supt., Combined Metals Reduction Co.

Minerals Beneficiation Division

Sunday Afternoon (2 p.m.)

Division Business Meeting.

Monday Morning

Coal Preparation

(Joint session with Coal Division; for papers see Coal Division)

Monday Afternoon

Grinding

Effect of Mill Speeds on Grinding Costs.	By Harlowe Hardinge and R. C. Ferguson.
Simultaneous Grinding and Flotation.	By A. Kenneth Schellinger and O. Cutler Shepard.
Ball Segregation in Grinding Mills.	By Fred C. Bond.
Jaw Crusher Capacities.	By D. H. Gieskieng.
Ball Mills for Grinding Cement Raw Materials.	By J. M. Wolfe.

Tuesday Morning

Flotation Practice

Flotation at Coronado Copper and Zinc Co.	By George A. Freeman.
Copper and Molybdenum.	By Charles Henry Curtis.
Barite Flotation.	By George H. Roseveare.
Flotation of Copper Silicate from Silica.	By R. W. Ludt and C. C. DeWitt.

Tuesday Noon

Division Luncheon; MBD members' ladies are welcome.

Tuesday Afternoon

Flotation Theory

Fluorite Flotation I: Development of New Flotation Technique.	By J. Hugh Hamilton, J. W. Johns, Jr., and Harold Bradford.
Fluorite Flotation, II: Theory of Oleic Acid Collector Action.	By Melvin A. Cooke and Arthur W. Last.
Studies on the Activation of Quartz with Calcium Ion, I.	By S. R. B. Cooke and Marcus Digré.
Studies on the Activation of Quartz with Calcium Ion, II.	By S. R. B. Cooke and Marcus Digré.
Mobility of Collector Ions and Effect upon Induction Time.	By Claude G. Myers, M. D. Hassialis, and A. F. Taggart.

Tuesday Afternoon

Pyrolysis and Agglomeration

(Joint session with Iron and Steel Division)

Sintering Characteristics of Minus Sixty-five and Twenty Mesh Magnetite.	By Alan Stanley and J. C. Mead.

Wednesday Morning

Hydrometallurgy

Charcoal Cyanidation.	By T. G. Chapman and V. W. Winters.
Effect of Variables in Countercurrent Decantation.	By E. A. Peretti.
Synthetic Ion Exchange Resins and Their Metallurgical Applications.	By V. W. Winters and Dr. Kunin.
Engineering Factors in Auto-oxidation Plant Design.	By Harmon Keyes.

Wednesday Afternoon

Hydrometallurgy

Plant-Scale Production of Dilute Sulphuric Acid by Auto-oxidation at Las Vegas, Nevada.	By D. N. Vedensky.
Sulphuric Acid from Sulphur Dioxide Gases by Catalytic Oxidation in Mechanical Cells.	By Carl Rampacek and J. Bruce Clemmer.
Recovery of Zinc by Dithionate Sulphur Dioxide Leaching Process.	By S. F. Ravitz and A. E. Back.
The Burt Filter.	By W. G. Woolf and A. Y. Bethune.

Wednesday Afternoon

(Joint session with Industrial Minerals Division)

The Noralyn Phosphate Concentration Operation.	
The Use of Rotary Trommels for 28-mesh Sizing.	

The Use of Humphreys Spirals with Reagentized Feed.

The Hydro Operation on Phosphatic Slimes.

Thursday Morning

Gravity Separation

Akins Separator for Heavy Media Separation—Garnet Ore.	By Herman Vogel.
Humphreys Spiral Concentration on Mesabi Range Ores.	By Whitman E. Brown and L. J. Erck.

Thursday Afternoon

"Clean-up" session; continuation from morning of general matters of interest to the Division.

Thursday Afternoon

Research Committee on Comminution.

Coal Division

Monday Morning

Preparation—Washing Western Coals
(Joint session with Minerals Beneficiation Division)

Coal Washing in Utah.	By Carl S. Westerberg, Utah Fuel Co.
Coal Washing in Colorado and New Mexico.	By J. D. Price and W. M. Bertholf, Colorado Fuel and Iron Corp.
Coal Washing in Washington, Oregon, and Alaska.	By M. R. Geer and H. F. Yancey, Bureau of Mines.

Monday Afternoon

Preparation—Coal Drying and Dewatering.

A Technical Study of Coal Drying.	By G. A. Vissac, consulting engineer.
Drying of Low-Rank Coals in the Entrained and Fluidized State.	By V. F. Parry, J. B. Goodman, and E. O. Wagner, Bureau of Mines.
The Rupp-Frantz Vibrating Filter.	By J. D. Price and W. M. Bertholf, Colorado Fuel and Iron Corp.

Monday Afternoon

5 p.m., Executive Committee, Coal Division.

Tuesday Morning

Preparation—Clarification of Washery Water and Classification of Anthracite.

Performance Tests of an Experimental Installation of Cyclone Thickeners at the Shamrock Mine.	By Thomas Fraser, Bureau of Mines; R. L. Sutherland, Truax-Traer Coal Co.; and F. F. Giese, Bureau of Mines.
Cyclone Operating Factors and Capacities on Coal and Refuse Slurries.	By Donald A. Dahlstrom, dept. chem. engng., Northwestern University.
Application of Screening and Classification for Improved Fine Anthracite Recovery.	By W. Julian Parton, Lehigh Navigation Coal Co.

Tuesday Noon

Coal Division Luncheon

Tuesday Afternoon

Mining; Diesel Locomotives Underground; Hoisting Coal Automatically

Proposed Method of Trackless Mining on Steeply Pitching High Coal Seam.	By H. C. Livingston, Union Pacific Coal Co.
Trends in Mechanical Loading and Strip Mining of Bituminous Coal.	By R. L. Anderson, Bureau of Mines.
Experience with Diesel Locomotives Underground at Blairmore.	By J. A. Brusset, West Canadian Collieries, Ltd.
Automatic Hoisting at the Snow Hill Coal Corporation.	By D. E. Renshaw, Westinghouse Electric Corp.

Wednesday Morning

Aerial Contour Mapping; Economics

Aerial Photographic Contour Maps for Strip Mines.	By George Hess, Aero Service Corp.
Mining Pillars, Under Heavy Cover, in a 16-ft Seam of Coal.	By George B. Jackson, Independent Coal and Coke Co.
The Economics of Coal for West Coast Power Generation.	By Claude P. Heiner, Utah Fuel Co.
Washington Coal, a Basic Industrial Resource of the Pacific Northwest.	By E. R. McMillan, Northwestern Improvement Co.

Wednesday Afternoon

Mining; Roof Control; LOX

Coal Mine Development in Alaska.	By A. L. Toenges, Bureau of Mines.
Roof Problems at Sunnyside, Utah.	By R. G. Heers, Kaiser Co.
The Use of Liquid Oxygen for Overburden Preparation in Open-Pit Mines.	By Dean Albin, Airite Corp.

Industrial Minerals Division

The program will extend through all four days of the meeting, starting Monday morning. Anticipated additions to the list of titles already submitted will require some revision and possibly some rearrangement of technical sessions, which as *Mining Engineering* goes to press, are tentatively scheduled as follows:

Monday Morning

Resources in the Industrial Minerals Field

Monday Afternoon

Mineral Economics

Tuesday Morning

Structural Materials

Tuesday Afternoon

New Products, Processes, and Techniques

Wednesday Morning

Phosphate Symposium

(Joint session with Mining Methods Committee; for program see Mining Methods)

Wednesday Noon

Industrial Minerals Division Luncheon.

Wednesday Afternoon

Noralyn Phosphate Washer

(Joint session with Minerals Beneficiation Division; for program see Minerals Beneficiation Division)

Thursday Morning

(Joint session on Titanium with Extractive Metallurgy and Iron and Steel Divisions; see Extractive Metallurgy Division)

Thursday Morning

Geology of Industrial Minerals

A partial list of the Industrial Minerals Division's Annual Meeting papers follows:

Economics of Western Phosphate.	By Roscoe E. Bell.
Reactive Aggregate in Concrete.	By R. F. Blanks and Roger Rhoades.
Guide for Buying Domestic Muscovite Mica.	By B. C. Burgess.
Strontium in the Northwest.	By William E. Caldwell.
A Geologic Study of the Perlite and Pumice Deposits of California.	By Charles W. Chesterman.
Processing of Southwestern Barite and Barite-fluorspar Ores.	By J. B. Clemmer, G. H. Roseveare, and Carl Rampacek.
Dolomite Resources of the Western States.	By Charles F. Deiss.
Talc Deposits of Gouverneur, New York.	By A. E. J. Engel.
Brazilian Ilmenite Sands.	By Joseph L. Gillson.
Portland Cement in the Pacific Northwest.	By K. E. Hamblen.
Geology of the Titanium Deposits of the Magnet Cove Area, Arkansas.	By D. F. Holbrook and V. C. Frykund.
Water and Power for Mining and Industry in California.	By Edward Hyatt.
Fuel Economy in the Lepol Kiln.	By Robert Kinzie.
Raw Materials Survey.	By R. B. Ladoo.
Lightweight Aggregate Industry in Oregon.	By R. S. Mason and N. S. Wagner.
Nonmetallic Mineral Resources of Arkansas.	By William B. Mather.
Preparation of Stereoscopic Micrographs.	By Louis Moyd.
Determination of Coefficients of Linear Thermal Expansion of Rocks by Means of Bonded Resistance Wire (SR-4) Strain Gauges.	By Louis Moyd.
Economics of Talc.	By Henry Mulryan.
Comparative Furnace Design for the Expansion of Perlite.	By John B. Murdock.
Water and Power Resources and Development in the Pacific Southwest.	By George C. Tenney and R. G. Folsom.
Geology of the Talc Deposits in California.	By Lauren Wright.
Economic Factors in the Production of Natural vs. Synthetic Magnesia.	By O. M. Wicken.
Flotation of Lepidolite at Keystone, South Dakota.	By A. I. Johnson.
Flotation of Spodumene at Tinton, South Dakota.	By A. I. Johnson.
Technical Utilization of Waste Pennsylvania Slate as a Lightweight Aggregate for Concrete.	By C. H. Moore, Jr.

Extractive Metallurgy Division

Monday Afternoon

Lead, Zinc, Cadmium

Electrolytic Zinc Plant at Risdon, Tasmania— Major Changes since 1936.	By S. W. Ross.
Fire Metallurgy of Cadmium.	By George T. Smith and Robert C. Moyer.
The Recovery of Cadmium from Cadmium-copper Precipitate.	By G. H. Anderson.
Cadmium Recovery Practice in Lead Smelting.	By P. C. Feddersen and Harold E. Lee.
The Zinc and Lead Industry in Germany Today.	By T. Benson Gyles.

Tuesday Morning

Lead and Zinc

The Effect of High Copper Content on the Operation of a Lead Blast Furnace, and Treatment of the Copper and Lead Produced.	By A. A. Collins.
Oxygen-enriched Air in the Lead Blast Furnace and Slag Fuming Furnace.	By R. R. McNaughton and associates.
Concentration of the Sulphur Dioxide Content of Dwight-Lloyd Sintering Machine Gas by Recirculation.	By W. S. Reid.

Autogenous Roasting of Low-grade Zinc Concentrate in Multiple-hearth Furnaces at Risdon, Tasm.	By J. A. B. Forster.

Wednesday Morning

Round Table

Discussion on Blast-furnace Charge Preparation and Dross Treatment.	Organized by R. R. McNaughton.
(A) Sinter Feed Preparation.	Introduction by Casper Nelson.
(B) Bullion Dross Treatment.	Introduction by A. A. Collins.

Wednesday Afternoon

Development of the Modern Zinc Retort.	By H. R. Page and A. E. Lee, Jr.
Controlled Drying of Retorts.	By R. R. Furlong and Donald Wertz.
Development of Muffle Furnaces for the Production of Zinc Oxide and Zinc at East Chicago, Indiana.	By Gunnard E. Johnson.
El Paso Slag Treatment Plant.	By T. J. Woodside.

4:30 p.m. EMD business meeting.

Thursday Morning

Titanium

(Joint session with Industrial Minerals and Iron and Steel Division)

Melting Points in the System TiO_2-CaO-MgO-Al_2O_3.	By H. Sigurdson and Sanford S. Cole.
Smelting of Titaniferous Ores.	By David L. Armant and Sanford S. Cole.
Petrology of High-titanium Slags.	By Charles H. Moore, Jr., H. Sigurdson, and D. L. Armant.
The Pilot-plant Smelting of Ilmenite in the Electric Furnace.	By C. Kerby Stoddard, Sanford S. Cole, L. T. Eck, and C. W. Davis.

Thursday Afternoon

The Morenci Smelter of Phelps Dodge Corporation at Morenci, Arizona.	By L. L. McDaniel.
Continuous Casting — The Asarco Process.	By A. A. Smith, Jr.
Distillation of Zinc From Copper Base Alloys and Galvanizers' Drosses.	By Frank F. Poland.
Reflections on the Electrolytic Cells Used in the Production of Aluminum.	By Bruno B. A. Luzzatto, consulting engineer.

Mining Geology

The Mining Geology Committee is meeting with the Society of Economic Geologists and the technical program is of joint origin except for Thursday afternoon.

Tuesday Morning

Mineral Resources and Ore Finding

National Mineral Resources Appraisal.	By S. G. Lasky, U. S. Geological Survey.
Research and Economic Geology.	By D. F. Hewett, U. S. Geological Survey.
Mining Geology and the Engineering Aspects of Mineral Exploration.	By J. D. Forrester, head, mining dept., Missouri School of Mines and Met.
Geochemical Prospecting for Ores; a Progress Report.	By H. E. Hawkes, U. S. Geological Survey.
Uniformatarianism and the Ideal Vein.	By Harrison Schmitt, consulting mining geologist.
Thermal Springs and Their Possible Significance in the Future Discovery of Ore Deposits.	By Donald E. White and George Thompson, U. S. Geological Survey.

Tuesday Noon

Mining Geology Committee Luncheon.

Tuesday Afternoon

Mineral Resources and Ore Finding

Lamprophyre and Ore—with Special Reference to British Columbia.	By H. C. Gunning, mining geologist, Canada.
Fracture Pattern in the Coeur d'Alene District, Idaho.	By Roger H. McConnel, Chief Geol., Bunker Hill and Sullivan Min. and Conc. Co.
Problems of Alteration and Mineralization at Silver Bell, Arizona.	By Paul F. Kerr, prof., mineralogy, Columbia Univ.
Hydrothermal Alteration at Bingham, Utah.	By Bronson Stringham, prof., geology, Univ. of Utah.
Recent Developments in the Western Iron Industry.	By R. F. Helmke, San Francisco.
The Copper Situation in Japan.	By J. J. Collins, Natural Resources Section, GHQ, SCAP.

Tuesday Evening

Society of Economic Geologists Dinner. Address by T. M. Broderick, retiring president.

Wednesday Morning

Mineral Resources and Ore Finding

Results from Preliminary Studies of Vein Formation at Butte.	By Reno H. Sales, formerly chief geol., and Charles Meyer, research geol., Anaconda Copper Mining Co.
Origin of the Bendigo Saddle Reefs with Comments on the Formation of Ribbon Quartz.	By Frederick M. Chace, USGS.
Geology of the Cerro Gordo Mine Area, California.	By Charles W. Merriam, USGS.
The Relationship of Contact-metamorphic Tungs-	By Paul C. Bateman, USGS.

ten Deposits to Regional Geology in the Bishop District, California.	
The Geology of the Massive Sulphide Deposits at Iron Mountain, Shasta County, California.	By A. R. Kinkel and J. P. Albers, USGS.
Vein Features in Ouachita Mineral Province, Ark.	By Albert E. J. Engel.

Wednesday Afternoon

Atomic Mineral Deposits

Impact of Atomic Energy on Economic Geology.	By J. K. Gustafson, Atomic Energy Commission.
Pitchblende Deposits of Vein Type.	By Philip L. Merritt, Atomic Energy Commission.
Characteristics of Marine Uranium-bearing Rocks.	By V. E. McKelvey and J. M. Nelson, USGS.
Uranium in Pegmatites.	By Lincoln R. Page, USGS.
Uranium-bearing Sandstone Deposits of the Colorado Plateau.	By R. P. Fisher, USGS.
Geology and Development of Radioactive Mineral Occurrences in Canada.	By W. F. James, Mining Geologist, Canada.

An exhibit of radioactive minerals and ores together with various laboratory and field Geiger counters, particularly a newly developed prospector's counter designed by the Geological Survey, is planned.

Thursday Afternoon

Society of Economic Geologists
Geology of Ground Water

Geology and Ground Water Resources of Cache Valley, Utah-Idaho.	By Philip F. Fix.
The Utilization of Induced Stream Infiltration and Natural Aquifer Storage at Canton, Ohio.	By R. G. Kazmann.
Paper by Nicolas Rose.	
Geologic Features Controlling Ground-water Occurrence and Yield in the West Basin of Los Angeles County, California.	By Joseph F. Poland.
Paper by Jack Graham.	

Mine Geology Trip

Edgar Bailey, USGS, who has spent several years mapping in detail the geology of the New Almaden quicksilver area, will be glad to show a group of geologists around the surface on Feb. 18 (or other date if preferred). The group will meet at Stanford University, Geology Building, at 9:30 a.m., where Mr. Bailey will have maps and sections, and will explain the geology of the area. From Stanford it is only half an hour by car to mine.

Geophysics

Thursday Morning and Afternoon

The following list is somewhat tentative as to inclusions and possible omissions. The papers will be arranged into sessions in the final program.

Results with the Aerial Magnetometer in South Africa.	By Oscar Weiss.
Some Gravimeter, Magnetic, and Electrical Surveys in Australia.	By Oscar Weiss.
Radioactivity Exploration with Geiger Counters.	By Henry Faul.
Temperature Compensation of Old-type Askania Magnetometers.	By Theodore Koulomzine.
Magnetic Fields Associated with Igneous Pipes in the Central Ozarks.	By Charles Holmes.
Gravimetric and Magnetic Survey of the Sudbury Nickel Region.	By George D. Garland and A. H. Miller.
Aerial Magnetic Surveys Above the Arctic Circle.	By Hans Lundberg.

Book Reviews

Application of Geology to Mining

Mining Geology. By Hugh Exton McKinstry. Prentice Hall, Inc., New York City. 1948. 680 p. $10.

REVIEWED BY IRA B. JORALEMON

"MINING GEOLOGY," by Hugh Exton McKinstry, is a most useful compilation of practical data on the application of geology to mining.

Part 1, entitled "Assembling Data," covers in detail the methods of geologic mapping, sampling of underground workings and of drill holes, geophysical investigations, and laboratory techniques used in connection with geological study. A final chapter on "Correlating Data" shows how the results of an examination can be recorded most effectively. This part of Dr. McKinstry's book will be invaluable to young geologists and engineers. It gives in 200 pages a summary of field and office methods that older engineers learn through many years of experience.

The only possible criticism of this part of the book is the fact that many authorities are quoted without an analysis of the relative validity of the methods of mapping or of sampling that they advocate. For instance, it is not clear just what method of com-

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Book Reviews

(*Continued from p. 38*)

bining diamond-drill core and sludge samples Dr. McKinstry thinks is best, and why. More comparisons of results of mining with estimates would help to show the limitations of sampling and would emphasize the usefulness of production statistics. The author's own conclusions would often have carried more weight than the authorities he quotes.

Part 2, entitled "Geological Principles of Ore Search and Ore Appraisal," is a remarkably clear and comprehensive description of the various geological guides to ore occurrences. These include physiographic, mineralogical, and structural guides, with an interesting chapter on faulting. Changes in ore with depth are particularly well analyzed. The great number of examples and of references to more detailed descriptions of mines add to the value of this part of Dr. McKinstry's work. With the help of the well organized index, an engineer or geologist can quickly find brief descriptions of other mines that have met with the problems that confront him, and can learn in a few minutes where he can get further data on any particular phase of ore occurrence. Part 2 will therefore not only be of great value to young geologists, but will also be a useful reference book for more experienced men who meet with unfamiliar structures or types of ore.

Part 3 of "Mining Geology" covers the application of geology to field exploration, the examination and valuation of mines and prospects, and geological work at an operating mine, both in finding ore and in assisting the mine operators. This section will save younger geologists much time in establishing an efficient technique. Older geologists will find suggestions that will help them make their work more exact and more economical of effort. Necessarily the legal aspects of mining and details of valuation are covered briefly, with references that will help those interested to obtain further information regarding these complex subjects. In future editions an expansion of the paragraphs on costs, with a distinction between "ton costs" and "pound costs," would add to the value of the chapter on valuation. An excellent chapter on "Writing and Reading Reports" closes this part of the book. Part 3 should be most useful in showing mineowners and operators what geology can be expected to do as well as in showing the geologists how to do it.

The final section of "Mining Geology," on "Amenability of Ore to Treat-

(*Continued on p. 40*)

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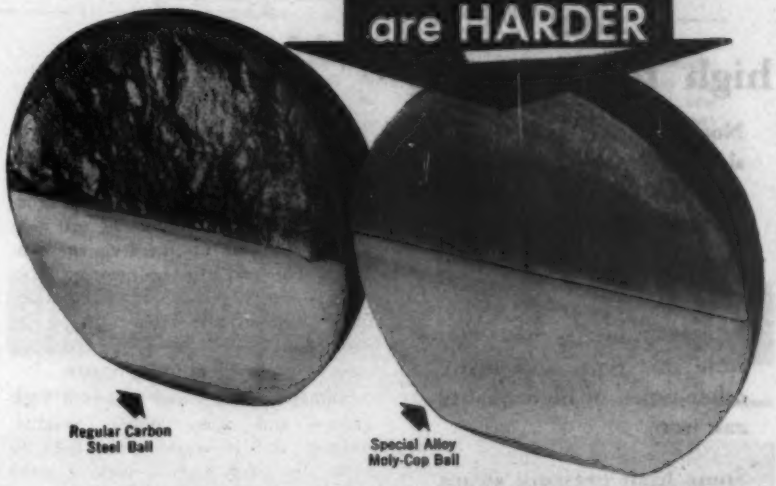

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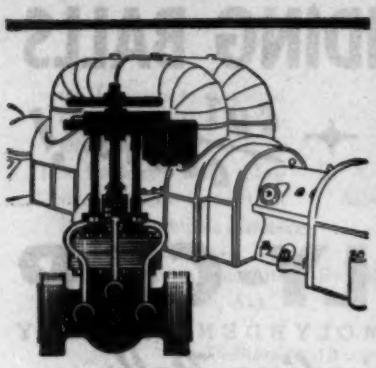

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Book Reviews

(*Continued from p. 39*)

ment," gives a brief résumé of metallurgical methods that can be used with different types of ores. The notes on recoveries and costs of various processes, with liquidation values, will help greatly to clear up the frequent confusion between gross content of ores and recoverable value. The lists of ore buyers and of marketable forms of the rarer metals as well as the common ones, are convenient for reference.

Valuation tables and tables of rock groups and ages, atomic weights, weights and measures, etc., help to make Dr. McKinstry's work a good handbook for geologists.

The many illustrations are of great value in helping to explain the geological problems. Hundreds of examples quoted from geological literature as well as those met with in Dr. McKinstry's wide experience show the staggering amount of work that must have gone into "Mining Geology." The simplicity of the style, with occasional flashes of humor, make the book pleasant reading.

Rand Mining Practice

Gold Mining on the Witwatersrand, Vols. 1 and 2. By C. Biccard Jeppe. Published by the Transvaal Chamber of Mines, Johannesburg. 1946. 1821 p.

WITH the increase in the price of gold in 1932, the mining of that precious metal expanded on the Witwatersrand as it did in most parts of the world. Wider areas, lower-grade ore, and deeper ore bodies became economic; and with this expansion came many changes in the technology and operational procedures. Mining practice prior to 1932 is described in "Witwatersrand Mining Practice," compiled by Watermeyer and Hoffenberg, but the many changes in the years following indicated the need for an up-to-date work. This monumental work was undertaken by Professor Jeppe at the suggestion of the Transvaal Chamber of Mines. Each branch of mining is dealt with in a separate chapter representing an entity or book in itself. The scheme adopted in dealing with each subject is first, to discuss the basic principles of that subject; second, the application of these principles to Witwatersrand mining practice (with reference, when relevant, to practice on other mining fields); and finally, the detailing of examples of such applications. Tables and drawings are used profusely to clarify the text.—*J.V.B.*

Factual Study of Saudi Arabia

Saudi Arabia. An account of the development of its natural resources. By Karl S. Twitchell with the collaboration of Edward J. Jurji. Princeton University Press. 1947. $2.50. 192 p.

THIS is an excellent factual and physical description of a little known area of the world. Mr. Twitchell is one of the few persons, among the non-Moslems, who has been permitted to travel throughout the country. This series of travels, covering a period of approximately twenty years, has enabled him to make the first comprehensive study of the economics, physical geology, agriculture, geography, and politics. No attempt has been made to present the information gained in the form of a text book, but rather it has been developed as a series of inter-related summaries which trace the history of the country as affected by climate, water supply, natural resources, and its political foundations as they are represented today.

It is apparent that the author has a deep and sincere feeling for the coun-

(*Continued on p. 41*)

Book Reviews

(*Continued from p. 40*)

try of which he writes, but it is also evident that he recognizes the shortcomings. His analysis of Saudi Arabia, its present development, and potentials, should do much toward increasing the interest of foreign countries and capital in providing a firm foundation for the future.—*E. P. Lange.*

Reference Guide

Sources of Engineering Information. By B. H. Dalton. University of California Press, Berkeley, Calif. 1948. $4. 109 p.

ANYONE who experiences confusion rather than enlightenment when doing research in a library will welcome this reference to references. The volume is a compilation listing source material on engineering and technical literature, and is arranged so that a technical man need only turn to a topic to find the key to all research previously published on that topic. Its coverage includes every type of engineering as well as less general subjects like industrial hygiene, paint, shellac, sugar, gaskets, and dams.

(*Continued on p. 42*)

Tremendous post-war engineering advancements have been made in the Hydrotator method of separation. Hydrotators and Hydrotator-Classifiers are now available for cleaning all sizes of anthracite, and in a complete range of capacities for all preparation plants. (Write Roberts & Schaefer Co., Chicago, about bituminous and metal mining applications.) Our new 120-page book describes the economies of the Hydrotator method; also data on other Wilmot coal preparation equipment.

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MINING ENGINEER, recent graduate, with degree from reputable school and aptitude for flotation work. Salary dependent on experience. Location, Colorado. Y1360.

ASSOCIATE PROFESSOR, with Ph.D. in optical mineralogy and ceramic petrography, and some practical experience in petrography and ceramic petrography. $4500 for nine months. Location, Missouri. Y1497C.

SALES ENGINEER, 35-45, mining graduate, sales experience in mining equipment field, preferably along electrical lines. Considerable traveling. $5000-$6000. Headquarters, New York City. Y1768.

MINING ENGINEER with fluorspar operating and managerial experience, to examine flourspar properties and prospects for investment purposes. $6000-$8000. Headquarters, New York City. Y1791.

ASSISTANT EDITOR, 25-30, metallurgical graduate, three to five years' experience in ore dressing or nonferrous smelting, to prepare and edit technical articles in mining and metallurgical field and visit mining operations to collect data. Knowledge of photography desirable. $4800-$5400. Location, New York City. Y1798.

ASSISTANT SUPERINTENDENT, 35-45, mining graduate, with considerable underground metal mining experience, to take charge of mining operations. $7200-$8400. Location, California. Y1802.

ENGINEERS. (a) Chemical engineer or chemist with oil refining experience, for process development of asphalt products. $3000-$4000. (b) Chemical engineer with oil refining experience, to run pilot plant tests on asphalts. $4000-$5000. Location, Maryland. Y1814.

SALES MANAGER, graduate engineer, with considerable industrial sales experience, particularly in mining equipment and conveyors. Experience in Virginia coal field desirable. Territories, West Virginia, Kentucky, Western Virginia. $9000 plus bonus. Y1881.

GEOLOGISTS with or without experience, for work in connection with flood control, navigation, and hydroelectric power development. Starting salary, $2974-$3727 a year, depending upon experience. Location, Arkansas. Y1879C.

Book Reviews

(Continued from p. 41)

Beneficiation of Oxide Zinc Ore

OXIDIZED zinc ore that is known to occur in fairly sizable quantities in Nuevo Leon, Mexico, was the subject of a beneficiation investigation carried out at the University of Missouri School of Mines and Metallurgy at Rolla. The results of the tests made show the ore cannot be treated by mineral dressing methods, but can by pyrometallurgical methods. They are written up by J. C. Nieto, A. Legadin, and A. W. Schlechten in the School's Bulletin of December 1947, vol. 18, No. 4.

Coal Dust and Its Control

El Problema del Polvo de Carbon en Las Minas. By Toron Villegas. Published for Banco de Mexico, Mexico, D. F. 491 p. 1948.

REVIEWED BY K. L. MARSHALL

THE Bank of Mexico has employed a group of engineers and specialists to prepare a series of industrial investigations which they hope will be helpful in increasing the industrial expansion of Mexico.

One of the principal series is a study of the carboniferous zones in Mexico and this book is an early release of a part of this study, which, as stated in its introduction, is brought out promptly because it covers a mining hazard, involving the lives of a large group of workmen now engaged in the exploitation of coal.

The writer has gathered and placed in this book, in the Spanish language, what may well be the most complete compilation of the research and investigations on the explosibility of coal dust and its control, to appear in any single book, in any language.

In this book we find references to investigations made as early as 1864 and to the formation of the earliest commissions to study the problem in France, England, Austria, and Germany, between 1879 and 1885.

The translations of the reports of studies in France, England, Germany and the United States, from these early dates to the present, are given in great detail and the writer records and compares the conclusions of these studies.

A section giving reports of the investigations of the major coal mine explosions throughout the world is very interesting, and the latter part of the book could well be used as a reference handbook on coal dust control and

(Continued on p. 44)

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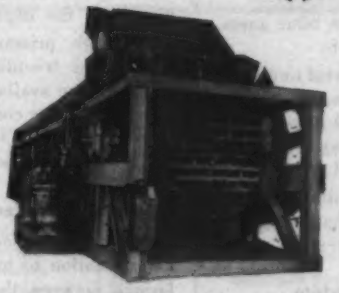

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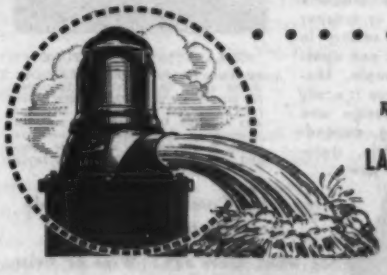

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Book Reviews

(*Continued from p. 42*)

neutralization, as well as on mine gases, their detection and analysis.

This last part can be useful to a mine official or mining engineer, who might wish to change from metal to coal mining, since the major universities in Mexico specialize in metal mining.

The book is profusely illustrated by photographs and graphs that add greatly to the clearness of the text.

In Pursuit of Freedom

IT'S a fine thing to be a mining engineer. That thought occurred to me when I finished reading a little booklet entitled "In Pursuit of Freedom" by Vivian V. Clark. Professor Clark tells the heart-warming story of the internment camp, Santo Tomas in Manila, where he spent over three years during the Japanese occupation of the Philippines. This is simply the story of how they spent their time and governed their community. It is under such circumstances, when the chips are really down, that a man's background and training either fit him to contribute to the well-being of the community or make him a burden to his fellows. Professor Clark and his fellow mining engineers, of whom there were more than a hundred at Santo Tomas, were in the forefront of those who lightened the burden of the imprisonment.

Although primarily written for his family and friends, a limited number of copies are available to those who desire them at the cost of publication, $1, by writing V. V. Clark, 845 South Lake St., Los Angeles 5.—*J.V.B.*

Bulletins of Interest

Mining Vocational Guide—With a determination to bring about closer relations between the field of education and the bituminous coal mining industry, the National Coal Association appointed a manager of vocational training to see what could be done to increase the flow of young men from the colleges and universities into the industry. Subsequently, he visited the United States schools that offer degrees in mining engineering. The outcome is the "Directory of Educational Institutions Maintaining Departments of Mining Engineering," a short guide to the history, courses of instruction, and members of the faculties of these schools, as they existed on June 1, 1948. The Directory is published by the National Coal Assn., Southern Building, Washington, D. C.

Canadian Coal—An "*Analysis Directory of Canadian Coals,*" *compiled by E. Swartzman,* has been published by the *Division of Fuels, Bureau of Mines, Ottawa, Canada.* These data on the chemical and physical properties of the various coals mined and marketed in Canada were first compiled and published in 1945. As coals *in situ* are not always uniform products, and as changes in mining and preparation also produce varying products, the analysis directory was made up to date. To maintain it as such, it will be revised again sometime within the next five years.

Data on Coal—Coal's intrinsic position in the world's economy gets further support in "Bituminous Coal Facts and Figures," a new data book covering all coal produced in the United States except Pennsylvania anthracite. Although published but recently, it already has a reputation for being the most complete ready reference handbook on coal ever issued. Its up-to-date information on reserves, production, distribution, and other subjects is presented in 148 pages of readable text, illustrations, and graphs. The Bituminous Coal Institute, which is responsible for the book, is making it available in libraries and universities.

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New Technical Books

Forming of Austenitic Chromium-Nickel Stainless Steels, assembled and edited by V. N. Krivobok and G. Sachs. International Nickel Co., 67 Wall St., New York. 1948. 309 p., illus., diagrs., charts, tables, 11¼ x 8½ in., cloth, $4.

This book gives fabricators of metal equipment a better understanding of the adaptability of stainless steels to all modern processes of forming. It presents a detailed description of the modern forming procedures as applied to chromium-nickel stainless steels and as practiced in United States plants. Bending and straight flanging, forming of curved sections and tubing, deep-drawing, die-forming, forming of contour flanged parts, and forming of miscellaneous methods are discussed. The specific examples of forming technique are supplemented by details of tool design and tool materials, lubricants, data on dimensions, and consecutive steps on fabrication.

Heat Conduction with Engineering and Geological Applications. By L. R. Ingersoll, O. J. Zobel, and A. C. Ingersoll. McGraw-Hill Book Co., New York, Toronto, London. 1948. 278 p., diagrs., charts, tables, 9¼ x 6 in., cloth, $4.

Based on the earlier text, "Theory of Heat Conduction," the present volume retains much of the old material, thoroughly revised, and provides new data. It contains many practical applications for the geologist and engineer, including such subjects as ground heat-pump sources, geysers, periodic flow, electric welding, and canning and drying operations. An outstanding feature is the chapter on graphical and other methods by which a large variety of heat-conduction problems may be solved with only the simplest mathematics.

(*Continued on p. 46*)

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Acting with characteristic energy, *Western Machinery Co.* of San Francisco already has established full sales and engineering service facilities for the Fagergren flotation machine, latest addition to the WEMCO line of machinery and equipment. Announcement was made in September that the well-known San Francisco firm had acquired exclusive manufacturing and sales rights for Fagergren cells, which previously were handled by the *American Cyanamid Co.*

Mine Timber Jack made by Templeton, Kenly & Co., Chicago, Ill., weighs 57 lb. Easily and safely lifts heavy timbers. Designed to reduce timbering costs.

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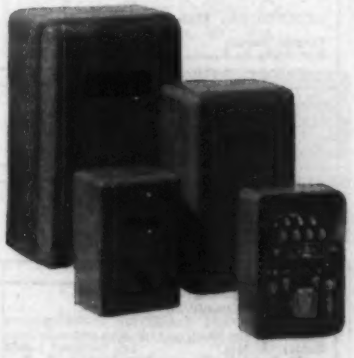

New line a-c **Magnetic Starters** now in production by General Electric Co. Important feature is the sturdy, one-piece plastic-encased coil enclosure which effectively protects the windings against dirt, moisture, or possible damage during installation.

Metallizing. To help readers solve their pump maintenance problems, METCO NEWS issued by the Metallizing Engineering Co. shows the savings possible by metallizing a wide range of pump parts, both centrifugal and reciprocating. Write to the company, 3814 30th St., Long Island City, N. Y.

The Model FDT-98W Side-dump Euclid, shown below, is the most recent addition to Euclid's line of off-the-highway earth moving equipment. The trailer body is of heavy welded construction for hauling rock, ore, and heavy excavation; it has a payload capacity of 40,000 lb. and a struck measure capacity of 13 cu. yd. Abil-

Euclid side-dump truck

ity to dump the load nonstop over the bank or edge of the fill makes this unit extremely versatile for mine, quarry, and other off-the-road hauling of heavy material. For further data write to the *Euclid Road Machinery Co.*, Cleveland, Ohio.

Personals

John Marshall Davis, metallurgical engineer, has joined the staff of *Western Machinery Co.*, with headquarters in the Southeast. Mr. Davis will be engaged in metallurgical sales and service work for the WEMCO Equipment Division and the *Western-Knapp Engineering Co.* Division of the firm in the Eastern territory of the United States.

Dan F. Beaton has joined the staff of *Western Machinery Co.* as sales engineer, with headquarters in Salt Lake City. Mr. Beaton will be concerned with metallurgical sales and service for the WEMCO Equipment Division and the *Western-Knapp Engineering Co.* Division of *Western Machinery Co.* in the Intermountain territory.

New Books

(*Continued from p. 44*)

ASTM Standards on Coal and Coke, prepared by ASTM Committee D-5, American Society for Testing Materials, 1916 Race St., Phila., Pa. Sept. 1948. 156 p., illus., diagrs., tables, 9 x 6 in., paper, $2. ($1.50 to ASTM members).

This publication brings together in convenient form the various ASTM methods of testing, definitions, and specifications for coal and coke, and the standard specifications for the classification of coal according to rank and grade. An appendix gives several proposed methods which the committee is studying.

ASM Review of Metal Literature, Vol. 4, 1947, edited by M. R. Hyslop. American Society for Metals, Cleveland 3, Ohio, 1948. 720 p., 9¼ x 6 in., fabrikoid, $15.

This comprehensive survey of the metallurgical literature published during 1947 continues the useful series started in 1944. The brief abstracts indicate the scope and content. In addition to the main classified arrangement of the items, a detailed subject index and an author index are provided. The addresses of the journals and periodicals abstracted are given. Both American and foreign literature are covered in the more than 8000 items included in the current volume.

Coal Mining in Australia. By H. S. Elford and M. R. McKeown. Tait Publishing Co. Pty. Ltd., Melbourne and Sydney, Australia, 1947. 247 p., illus., diagrs., charts, tables, maps, 11¼ x 8¼ in., cloth, 15s.

Part I of this survey covers geology and coal deposits, methods of mining, use of mechanical equipment, safety, and the preparation of higher quality coal by treatment of the as-mined coal. Part II gives a description of the operations at a number of coal mines, selected because of one or more features of special interest. The publication is liberally illustrated by diagrams and photographs.

Drilling and Production Practice 1947, Division of Production, American Petroleum Institute, 50 West 50th St., New York. 1948. 322 p., illus., diagrs., charts, tables, 10¾ x 8 in., cloth, $5.

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New Books

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The present volume of this annual publication presents 24 papers grouped in four sections: drilling practice; production practice and technology; materials; and miscellaneous developments. A wide variety of topics is covered from the flow properties of drilling muds to P-V-T correlation for oil and gas mixtures. In addition, the volume contains a bibliography (with abstracts of papers not reproduced in full in this volume) of all papers presented at district meetings in 1947.

Fuel and the Future, 3 Vol. Great Britain, Ministry of Fuel and Power. Publ. by His Majesty's Stationery Office, 429 Oxford Street, London, W.1, England, 1948. Diagrs., charts, tables, 9½ x 6 in., paper, Vol. 1, 370 p., 6s.; Vol. 2, 374 p., 6s.; Vol. 3, 211 p., 3s.6d.

Vol. 1 of this report of an officially convened conference deals with the generation of steam, steam utilization, and heat for drying. Vol. 2 covers high temperature processes, the carbonization and chemical industries, and several special industrial sessions. Vol. 3 presents modern heating in relation to the architect and fuel services in the home. Two simultaneous joint sessions on district heating and the sizing and grading of coal are also included.

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Announcement

This year our famous Annual Review Issue will be published in MARCH. But we have a new publishing schedule, so for each issue we must have Space Reservations not later than the 8th of the preceding month — then Advertising Plates must be in New York by the 15th. Always reserve space at least a week before plates are due in New York.

MARCH 1949

ANNUAL REVIEW ISSUE

MINING ENGINEERING

37 Authoritative Engineers will write special articles for this March Issue

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